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VOLUME 2

PRELIMINARY DESIGN AND DEVELOPMENT OF THE INTERMEDIATE WATER RECOVERY SYSTEM

Report No. 70-7018, Rev. 1
March 12, 1971

Combined Final Reports on Contracts
NAS 9-8460
NAS 9-9981

Prepared for

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas

GARRETT

AIRESEARCH MANUFACTURING COMPANY
Los Angeles, California

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A DIVISION OF THE GARRETT CORPORATION

LOS ANGELES, CALIFORNIA

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FOREWORD

This report was prepared by the AiResearch Manufacturing Company of Los Angeles to summarize the results of two programs sponsored by the Manned Spacecraft Center of the National Aeronautics and Space Administration under Contracts NAS 9-8460 (Task B) and NAS 9-9981. These two programs were conducted simultaneously and were concerned with (1) the preliminary design for an Intermediate Water Recovery System (NAS 9-8460) and (2) the design of an Intermediary Water Recovery System (NAS 9-9981). The first contract involved system analyses, which culminated in the preparation of a system specification; the second was concerned with the development of a breadboard unit to provide data for system design. The interactions between the program were such that a single report was deemed more informative and more logical than two separate reports, each covering the activities of a single contract.

Contract NAS 9-8460, Task A, was initiated in September, 1968, and was concluded with the submittal of the Task A final report (AiResearch Report No. 69-5470) in August, 1969.

The overall period of performance of the two contract covering the activities reported here was from September 1969 to December 1970.

Initially, Mr. Dean Thompson of NASA MCS was the program technical monitor; Mr. Don Hughes was appointed to this post in February 1970. At AiResearch, the program manager was Mr. A. H. Bauer.

AiResearch personnel who contributed substantially to these programs include: O. Morton, C. Albright, K. Ikeda, W. Hendrickson, and J. Rousseau.

The report is divided in two volumes, Volume I contains the results or the investigations conducted, Volume 2 contains the appendices. This is Volume 2.

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PRELIMINARY COMPONENT PERFORMANCE SPECIFICATIONS

This appendix contains preliminary specifications for all system components. Data given include:

(a) Purpose

(b) Description

(c) Performance and design data

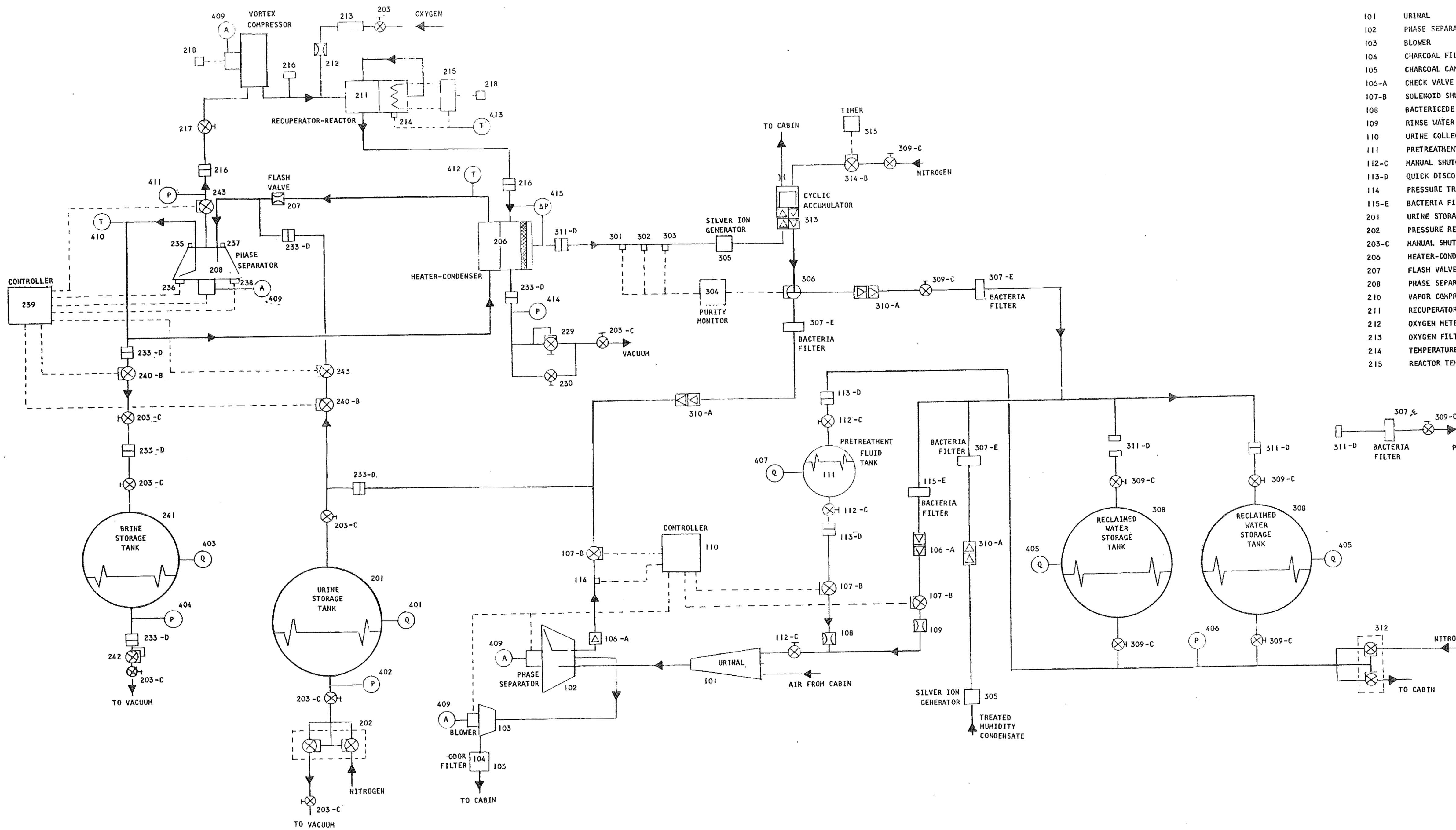
The performance requirements were based on a system design point defined as follows:

(a) Brine concentration: 20 percent

(b) Condenser pressure: 1.5 psia

(c) Water processing rate: 1.38 lb/hr

Figure A-1 is included showing the arrangement. Table A-2 gives the summary of the components characteristics.



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L-63871

Figure A-1. System Schematic

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TABLE A-1
COMPONENT SUMMARY

Item Number	Description	Number Required	Item Weight, lb	Power, Watts	Remarks
100--URINE COLLECTION AND TRANSFER					
101	Urinal	1	1	-	Incorporates air and water manifolds
102	Phase separator	1	10	20	Brushless dc motor drive; statically sealed unit
103	Blower	1	4	10	Brushless dc motor drive; ΔP = 3.5 in. H_2O
104	Charcoal filter	1	1.5	-	Expendable; charcoal impregnated with phosphoric acid
105	Charcoal canister	1	2.5	-	Rechargable every 90 days
106-A	Check valve	3	0.1	-	
107-B	Solenoid shutoff valve	3	0.3	See remarks	Spring loaded closed - 6 watts to activate by Item 110
108	Bactericide metering orifice	1	0.1	-	
109	Rinse water metering orifice	1	0.1	-	
110	Urine collection package controller	1	3.0	60	Power includes power to valves and motors
111	Pretreatment fluid tank	1	11 (full)	-	Contains 7 lb of pretreatment fluid; replaced at 90-day intervals
112-C	Manual shutoff valve	3	0.3	-	
113-D	Quick disconnects	2	0.8	-	
114	Pressure transducer	1	1.0	-	40 ma at 28 vdc
115-E	Bacteria filter	1	0.2	-	
200--URINE STORAGE AND PROCESSING					
201	Urine storage tank	1	8 (dry)	-	Capacity: 37.6 H_2O; operating pressure: 4 to 7 psia
202	Pressure regulator-relief	1	1	-	Regulates at 4 psia, relieves at 7 psia
203-C	Manual shutoff valve	8	0.3	-	
206	Heater-condenser	1	5	-	1440 Btu/hr capacity at design point (20 percent brine concentration)
207	Flash valve	1	0.1	-	
208	Phase separator	1	10	60	Brushless dc motor; magnetic coupling; brine ΔP: 10 psi
210	Vapor compressor	1	8	80	Brushless dc motor; magnetic coupling; pressure ratio: 1.59 at design point
211	Recuperator-reactor	1	5	25	Contains rhodium catalyst; operating temperature: 800°F
212	Oxygen metering orifice	1	0.1	-	O_2 flow controlled at 0.0005 lb/hr
213	Oxygen filter	1	0.2	-	
214	Temperature sensor	2	0.1	-	
215	Reactor temperature controller	2	0.6	40	Power includes reactor power input
216	Quick-disconnect	3	1.0	-	
217	Manual shutoff valve	1	0.7	-	Similar to -C valve
218	Switch	2	0.1	-	
229	Condenser pressure regulator	1	1.0	-	Adjustable aneroid to permit regulation between 0.5 and 2.5 psia
230	Bleed valve	1	0.2	-	Limit depressurization of vapor drop at rate of 0.5 psi/min
233-D	Quick-disconnect	6	0.8	-	
235	Density control source	1	0.6	-	Nucleonic source (americium 241)
236	Density control detector	1		-	Geiger-muller tubes
237	Level control source	1	0.6	-	Americium 241 source
238	Level control detector	1		-	Gieger mueller tubes
239	Brine loop controller	1	3	85	Manage fluid inventory in brine loop; power includes powerr for valve and separator operation
240-B	Solenoid shutoff valve	2	0.3	See remarks	Spring loaded closed; 6 watts to open
241	Brine storage tank	1	12 (dry)	-	Capacity: 94 lb of 50 percent solids brine; pressure 4 to 6 psia
242	Brine pressure regulator	1	1.0	-	
243	Solenoid shutoff valve	2	0.3	-	Normally opened; 6 watts to open

TABLE A-1 (Continued)

Item Number	Description	Number Required	Item Weight, lb	Power, watts	Remarks
300--RECLAIMED WATER COLLECTION AND TRANSFER					
301	pH sensor and display	1	0.2	-	
302	Conductivity sensor	1	0.2	-	
303	Inorganics monitor	1	1.0	-	
304	Purity controller	1	2.5	25	32 watts maximum when selector valve actuated; display meters on unit
305	Silver ion generator	2	0.7	-	Self-contained electronic unit
306	Selector valve	1	0.8	-	6 watts required for actuation; valve actuated when water unacceptable
307-E	Bacteria filter	4	0.2		
308	Reclaimed water tank	2	6 (dry)	-	Capacity: 20 lb of water
309-C	Manual shutoff valve	7	0.3	-	
310-A	Check valve	6	0.1	-	
311-D	Quick disconnect	4	0.8	-	
312	Pressure regulator-relief	1	1.0	-	Maintains reclaimed water tank at 30 psig
313	Cyclic accumulator	1	2.0	-	Powered by nitrogen from spacecraft supply
314-B	Solenoid valve	1	0.3	-	Powered by timer (315)
315	Cyclic accumulator timer	1	0.5	5	Also 7 watts for activation of valve 314-B
400--INSTRUMENTATION					
401	Urine storage quantity meter	1	0.7	40	Range: 0 to 40 lb
402	Urine storage pressure meter	1	0.8	30	Range: 0 to 8 psia
403	Brine storage quantity meter	1	0.7	40	Range: 0 to 110 lb
404	Brine storage pressure meter	1	0.8	30	Range: 0 to 8 psia
405	Reclaimed water storage quantity meter	1	0.7	40	Range: 0 to 20 lb
406	Reclaimed water storage pressure meter	1	0.8	30	Range: 0 to 40 psig
407	Pretreatment tank quantity meter	1	0.7	40	
409	Ammeter	4	0.5	1 to 4	Range: 0 to 5 amps
410	Brine temperature-separator outlet	1	0.7	40	Range: 80 to 130°F
411	Separator pressure meter	1	0.8	40	Range: 0.2 to 3.0 psia
412	Brine temperature-condenser outlet		0.7	40	Range: 80 to 130°F
413	Catalytic reactor temperature	1	0.7	40	Range: 600 to 1000°F
414	Condenser pressure transducer	1	0.8	40	Range: 0.2 to 3 psia
415	Differential pressure transducer	1	0.8	40	Range: 0 to 0.5 psia

ITEM 101

URINAL

PURPOSE

The urinal is used to collect urine for transfer to the phase separator (102).

DESCRIPTION

The urinal is of an open funnel-cup shaped design and is connected to a 3 ft length of 1/2 inch ID flexible transparent transfer tube. A rinse water line is integral with the transfer tube. The urinal incorporates numerous holes in the cup housing to permit cabin gas to flow into the urinal and to allow cleansing with fresh water with pretreatment fluid after micturation. The pneumatic force of the cabin gas transfers the urine or the rinse water from the urinal to the phase separator (102). A blower (103) assures gas circulation through the system.

PERFORMANCE AND DESIGN REQUIREMENTS

Urine flow rate, cc/sec	20 (nominal)
	50 (maximum)
Cabin gas flow rate, cfm	6
Rinse water flow rate, cc/sec	30
Pressure drop, in. H_2O	2 maximum
Weight, lb	1

ITEM 102

PHASE SEPARATOR

PURPOSE

The phase separator is used in the urinal loop to separate the entrained cabin gas from the urine and rinse water mixture. The separator serves as an accumulator during micturation and rinsing. The liquid is pumped out of the separator to the urine storage tank (201) after completion of the micturation and rinsing cycles. The air is drawn from the separator by the blower (103) downstream of the separator.

DESCRIPTION

The phase separator consists of a rotating drum with a stationary pitot tube which serves as a pump. The mixture of liquid and gas enters the drum through a stationary delivery tube near the axis of rotation. Due to centrifugal force, the liquid is forced against the periphery of the drum while the gas collects at the center from where it is exhausted from the unit. The pitot tube inlet located near the drum periphery removes the high velocity liquid and pumps it to the urine storage tank (201). A brushless dc motor drives the drum through a magnetic coupling. The unit has no dynamic seals.

PERFORMANCE AND DESIGN REQUIREMENTS

Drum capacity, cc	350 - 500
Discharge flow rate, lb/hr	100
Gas flow rate, cfm	6
Gas pressure drop, in. H_2O	0.5
Discharge gas pressure, psia	5 to 7
Discharge liquid pressure, psig	5 to 7
Residual water at 0.5 psig discharge pressure, cc	10
Airflow out of separater at 0.5 psia discharge pressure, cfm	0
Power, watts	20 max with 28 ±4 vdc input
Drum rotational speed, rmp	1400
Drum diameter, inch	6
Weight, lb	10

ITEM 103

BLOWER

PURPOSE

The blower provides the gas flow necessary for zero-gravity transport of urine from the urinal to the phase separator. The gas blower draws cabin air into the urinal (101) and returns the air to the cabin after it is separated from the urine in the separator (102) and filtered in a bacterial/activated charcoal filter (104).

DESCRIPTION

This blower is a centrifugal unit driven by a brushless dc motor.

PERFORMANCE AND DESIGN REQUIREMENTS

Flow rate, cfm	6
Pressure rise, in. H_2O	3.5
Outlet pressure, psia	5.02 psia for a 5 psia cabin
Input voltage, volts dc	28 ±4
Envelope, in.	4 dia x 5
Power consumption, watts	10
Estimated weight, lb	4

ITEM 104 AND 105

ODOR FILTER

PURPOSE

The odor filter is used to remove odors from the gas circulated through the urinal loop. After deodorizing, the gas is returned to the cabin.

DESCRIPTION

The odor filter is installed at the discharge of the urinal loop gas blower, (103). The filter consists of a housing assembly (105) and a replaceable charcoal charge (104). The housing assembly is designed to allow easy replacement of the charge every 90 days.

The expendable charge consists of a metal shell packed with 6 - 10 mesh activated charcoal impregnated with phosphoric acid. The charcoal readily adsorbs gas of moderate-to-high molecular weight which includes most odors. The phosphoric acid removes ammonia and checks bacteria growth on the filter element.

PERFORMANCE AND DESIGN REQUIREMENTS

Activated charcoal	AC-4
Flow rate, cfm	6
Pressure drop, in. H_2O	0.4 max
Enclosure, in.	6 x 6 x 3
Expendable charcoal weight, lb	1.3
Total odor filter weight, lb	4

ITEM 106-A

CHECK VALVE

PURPOSE

This check valve is used to prevent reverse flow of liquid in critical parts of the water circuit. This valve is also used in other subsystems.

DESCRIPTION

The valve consists of a elastomer, umbrella-shaped valve and a flat metal seat. The seat has a series of holes, arranged in a circle of lesser diameter than the valve, to allow through flow. When installed, the valve is slightly preloaded to seal at its outer periphery. If pressure is applied in the flow direction, the valve is forced away from the seat, allowing water to pass through the holes in the seat. If pressure is applied in the reverse direction, the valve is forced against the seat, checking flow by covering the holes in the seat. A retainer prevents the valve from tearing away from its seat in the event of a high transient pressure in the flow direction. The valve is designed for low pressure drop in the flow direction and negligible leakage in the check direction.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating pressure	Inlet, 37 psig maximum
	Reverse, 37 psi above inlet
Inlet temperature	40 to 150°F
Effluent	Water, urine, pretreatment fluid, wash water
Flow rate with inlet water at 75°F and 20 psig	200 lb/hr with 0.4 psi max ΔP
Proof pressure	56 psig normal. In reverse direction, psi above inlet
Burst pressure	93 psig normal. In reverse direction, 93 psi above inlet
Line size	1/4 inch
Weight	0.1 lb

ITEM 107-B

SOLENOID SHUTOFF VALVE

PURPOSE

This valve controls the flow of liquids in the urine collection loop. It is actuated by the urine loop controller (110). It is used at three locations in the package: (1) at phase separator outlet (240-B), (2) in the pretreatment fluid supply line (107-B), and (3) in the flush water supply line (107-B).

DESCRIPTION

This valve is normally spring-loaded closed and is fully opened when supplied with 28 vdc power from the urinal loop controller (110). Flow control where necessary is effected by means of orifices downstream of the valve.

PERFORMANCE AND DESIGN REQUIREMENTS

Nature of fluid	Water Pretreatment fluid (39.8 percent H_2SO_4, 9.8 percent CrO_3, 3.1 percent $CuSO_4$, 47.3 percent water) Urine
Flowrate	12 cc/sec with a ΔP of 0.2 psi max
Maximum pressure, psig	27
Operating temperature range, $^{\circ}F$	40 to 150
Operating power (28 vdc input), watts	6 maximum
Proof pressure, psig	56
Burst pressure, psig	93
Weight, lb	0.3

ITEM 110

URINAL CYCLE CONTROLLER

PURPOSE

The cycle controller is used to automatically operate the urinal loop solenoid shutoff valves (107), phase separator (102), and blower (103).

DESCRIPTION

The controller is an integral unit containing solid-state components. The unit employs timer circuits and static switches to operate the external interfacing electrical components at the required time following micturation. The input signal from a pressure switch (114) is used to shut off the solenoid valve at phase separator outlet after the unit is empty. The controller also deactivates the separator and blower motor after the drying cycle.

PERFORMANCE AND DESIGN REQUIREMENTS

Sequence of urinal loop control functions

1. Prior to micturation, power is supplied to the phase separator and the gas blower. The phase separator outlet solenoid valve (107) is not energized and is spring loaded closed to prevent carryover of cabin gas into the urine supply circuit during micturation.

2. After micturation, the selector switch is positioned to initiate automatic operation of the cycle controller and interfacing electrical components.

3. When the cycle controller is activated, it provides power to the separator outlet solenoid valve (107) which opens to allow urine to flow from the phase separator to the urine supply circuit.

4. When the pressure sensed by the pressure switch (114) drops below 0.5 psig, the controller deactivates the separator outlet solenoid valve (107).

5. Five seconds after the solenoid valve is deactivated, the controller energizes the rinse water solenoid valve (107). This valve remains energized for 14 ± 1 seconds.

6. Six seconds after the rinse water solenoid valve (107) is energized, the solenoid valve (107) to pretreatment fluid tank is energized for 2.0 $+0$, -0.3 seconds.

ITEM 110 (Continued)

7. Five seconds after the rinse water solenoid valve (107) is deenergized, the separator outlet solenoid valve is energized to allow liquid outflow from the phase separator. This valve remains open until the phase separator outlet pressure switch senses a pressure less than 0.5 psig.

8. Five minutes after the separator outlet solenoid valve is closed, the phase separator and the blower are simultaneously deactivated.

9. The selector switch is returned to the "OFF" position.

Output power at 28 ±4 vdc, watts	
For phase separator	20
For gas blower	10
For three solenoid valves	6 for each valve
Input power, watts	60 maximum at 28 ±4 vdc input
Weight, lb	3

ITEM III

PRETREATMENT FLUID TANK

PURPOSE

The tank is used to store the pretreatment fluid required for urinal circuit cleansing. The tank is replaced every 90 days.

DESCRIPTION

The tank is spherical and has a volume of 0.13 ft^3. Expulsion of bactericide is provided by a bladder pressurized with nitrogen at 30 psig.

PERFORMANCE AND DESIGN REQUIREMENTS

Maximum storage capacity, ft^3	0.130
Nature of pretreatment fluid	39.8 percent H_2SO_4, 9.8 percent CrO_3, 3.1 percent $CuSO_4$, 47.3 percent water
Expulsion gas pressure, psig	30 ±2
Expulsion gas relief pressure, psig	37
Due to open failure of pressure regulator, psig	110
Fluid temperature range, ^0F	40 to 150
Proof pressure (1.5 times max press of 110 psig), psig	165
Burst pressure (2.5 times max press of 110 psig), psig	275
Weight, lb	4 empty (11 lb full)

ITEM 112-C

MANUAL SHUTOFF VALVE

PURPOSE

This valve is used at three locations in the urine collection subsystem: (1) in the nitrogen line to the pretreatment fluid tank, (2) in the pretreatment fluid line, and (3) in the urinal flush water line.

DESCRIPTION

The valve contains a manually-operated poppet to restrict the flow through the unit. The poppet is integrally connected to a bellows that serves as a static and dynamic seal for preventing external leakage. A quarter turn of the handle is required to move the poppet from the full-closed position to the full-open position.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating pressure, psig	30 $\pm$2 normal
Inlet temperature, ^{0}F	40 to 150
Flow rate	1 cc/sec
Proof pressure, psig	165
Burst pressure, psig	275
Line size, inch	1/4
Operating torque, in.-lb	5 maximum
Weight, lb	0.3

ITEM 113-D

LIQUID DISCONNECT COUPLINGS

PURPOSE

The quick-disconnect couplings provide the capability for quick replacement of the pretreatment tank at regular resupply time.

DESCRIPTION

Each connection consists of half of a self-sealing poppet type quick-disconnect fluid coupling. The poppet is spring loaded in the closed position and opens upon connection with the mating half coupling. The poppet in one coupling fits flush against the poppet in the mating coupling to prevent the inclusion of air into the system during connection. Each coupling is provided with a cover.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating Pressure	0.5 to 40 psig liquid with 5 to 15 psia ambient
Flow rate for water at 75°F and 20 psig	150 lb/hr at 0.5 psi maximum ΔP
Spillage	0.05 cc maximum per connection or disconnection
Connecting force, lb	10
Proof pressure, psig	60 (mated and unmated). Also, 23 psig reverse pressure (unmated)
Burst pressure, psig	100 (unmated)
Weight, lb	0.8

ITEM 114

PRESSURE SWITCH

PURPOSE

This pressure switch is used to sense the liquid pressure at the outlet of the phase separator (102). The output signal is supplied to the urinal controller (110) which shuts the solenoid valve at separator outlet when the sensed liquid pressure drops below a given limit.

DESCRIPTION

The pressure switch solid-state circuitry is powered by the 28 vdc supply of the spacecraft and provides an output signal indicative of the liquid level (low or high) within the phase separator. The sensing element is a flat diaphragm of stainless steel, clamped between case halves of the same material. The diaphragm deflection is sensed by pickoff coils located on one side of the diaphragm.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating pressure, psig	0 to 1
Temperature range, ^{0}F	40 to 150
Output for sensed pressure less than 0.5 psig	2 volts
Output for sensed pressure greater than 0.5 psig	0
Pressure switching limits, psig	0.45 to 0.55
Input current at 28 ±4 vdc, ma	40 max
Proof pressure, psig	11
Burst pressure, psig	18
Weight, lb	1

ITEM 115-E

BACTERIA FILTER

PURPOSE

This filter is installed in the line between the reclaimed water supply and the urinal (101) to prevent the passage of bacteria into the reclaimed water circuit.

DESCRIPTION

The filter is an inline mounted unit employing a microporous element which serves as a mechanical barrier to bacteria. Water from the reclaimed water supply will contain silver ions which will prevent bacteria growth on the surface of the filter. The filter is easily replaceable.

PERFORMANCE AND DESIGN REQUIREMENTS

Flow, lb/hr	10 at 2 psi maximum ΔP
Operating fluid	Water
Inlet pressure, psig	30
Operating temperature, ^{o}F	40 to 150
Filtration size, micron	0.10 to 0.15
Proof pressure, psig	165
Burst pressure, psig	275
Weight, lb	0.2

ITEM 201

URINE STORAGE TANK

PURPOSE

The urine supply tank is used to store urine feed required for the urine water recovery subsystem. The tank is sized for 2 days storage of urine and urinal rinse water (33.0 lb of urine and urine rinse water).

DESCRIPTION

The tank is cylindrical and has a volume of 0.6 ft^3. Expulsion of urine feed is provided by a bladder pressurized with 6 psia nitrogen. The bladder is attached at both ends of the tank. When the tank is filled, the bladder is fully collapsed.

PERFORMANCE AND DESIGN REQUIREMENTS

Storage capacity, ft^3 (includes 15 percent ullage)	0.6 at 150°F
Storage capacity, lb	37.6
Expulsion gas pressure, psia	4.0 ±0.5
Expulsion gas relief pressure, psia	7 ±0.5
Maximum pressure due to open failure of pressure regulator, psig	110
Brine temperature range, °F	70 - 150
Proof pressure (1.5 times max press of 110 psig), psig	165 on N_2 side
	165 on water side
Burst pressure (2.5 times max press of 110 psig), psig	275 on N_2 side
	275 on water side
Envelope, in.	12 1/2 dia x 11
Weight, lb	8 empty

ITEM 202

REGULATOR-RELIEF VALVE

PURPOSE

The unit provides regulated gas pressure to the urine storage tank (201) for positive expulsion and transfer of urine feed to the recirculating urine brine loop. An integral relief valve prevents overpressurization of the urine storage tank.

DESCRIPTION

The unit consists of an absolute pressure regulator and a relief valve. The pressure regulator contains a normally-open, aneroid-operated metering valve which maintains the sensed pressure at 4 psia nominal.

The relief valve is located in the outlet chamber of the unit. It vents excess pressure to vacuum to limit the sensed pressure to 7.5 psia maximum. Operation of the relief valve is similar to that of the pressure regulator except that the valve is normally closed.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating fluid	Gaseous nitrogen
Inlet pressure range, psia	85 to 115
Regulated outlet pressure, psia	4 ±0.5
Flow, lb/hr	4 to 8 at inlet of 85 psia
Relief pressure, psia	7.0 ±0.5
Regulator leakage, sccm	10 at inlet of 115 psia and outlet of 9 psia with ambient at 5 psia
Relief leakage, scc/hr	5 at outlet of 9 psia with ambient at 5 psia
Proof pressure, psig	210 at inlet
Burst pressure, psig	350 at inlet
Line size, in.	1/4
Weight, lb	1

ITEM 203-C

MANUAL SHUTOFF VALVE

(SEE ITEM 112-C)

ITEM 206

HEATER/CONDENSER

PURPOSE

In this unit the liquid brine is heated by the condensing vapor.

DESCRIPTION

The brine flows through a single tube arranged in two concentric cylindrical helixes. Cylindrical refrasil wicks are in contact with the coils. The vapor entering the unit flows in the passages formed by the tube and the wicks in a counterflow manner through the first helix and in a parallel flow path through the second one. Vapor condenses outside the tube. The condensate is collected by the wicks and transported to a hydrophilic sintered metal plate. A pressure differential across the plate assures liquid water flow through the plate and out of the unit while presenting a barrier to gas and vapor flow. This pressure differential is imposed upon the plate by the cyclic accumulator (313). Non condensible gases saturated with water vapor are continuously bled from the unit and dumped overboard. Pressure regulator (229) provides this function.

PERFORMANCE AND DESIGN REQUIREMENTS

Inlet brine temperature, ^{0}F	107
Inlet brine concentration, ±	20 percent solids
Brine flow rate, lb/hr	202
Brine side pressure drop, psi	4.5 maximum at 20 percent solids brine flow of 202 lb/hr and $100^{0}F$
Inlet brine pressure, psia	10 with 5 psia cabin
Brine side temperature rise, ^{0}F	8 minimum
Inlet vapor temperature, ^{0}F	121
Inlet vapor pressure, psia	1.50
Vapor flow rate, lb/hr	1.38
Noncondensible vent pressure, psia	1.5
Heat transfer rate, Btu/hr	1440(minimum flow)
Ambient heat loss, Btu/hr	60 maximum

ITEM 206 (Continued)

Proof pressure	
Brine side, psig	33 with steam side at ambient pressure
Vapor side, psig	33 with condensate outlet port capped
Burst pressure	
Brine side, psig	55 with steam side at ambient pressure
Vapor side, psig	55 with condensate outlet port capped
Weight, lb	5

ITEM 207

FLASH VALVE

PURPOSE

This valve is installed in the brine loop upstream of the phase separator (208). The valve reduces the pressure of the brine passing through it below saturation pressure. As a result a portion of the water contained in the brine will be flashed to vapor across this valve.

DESCRIPTION

The valve is an orifice sized to obtain the required flashing characteristics.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating pressure, psia	3 to 5 at inlet
Maximum pressure, psia	Internal 5 and external 14.7
Inlet temperature, ^{0}F	40 - 150
Flow at inlet brine of $105^{0}F$ and ΔP of 2.25 psi, lb/hr	202 nominal. Should be capable of 250
Brine	0 to 50 percent solids
Effective CA, sq in.	0.00731 sq in. (liquid)
Proof pressure, psig	33
Burst pressure, psig	55
Line size, inch	1/4
Weight, lb	0.1

ITEM 208

PHASE SEPARATOR

PURPOSE

The separator is used in the brine loop to separate the water vapor from the urine brine and to pump the brine through the system. The separator also serves as an accumulator-surge tank for the liquid brine.

DESCRIPTION

The separator consists of a motor-driven drum in which is located a stationary pitot tube which is used as a pump. The mixture of urine brine and water vapor leaving the flash valve (207) enters the drum through a stationary delivery tube passing through one end of the drum. Due to centrifugal force, the liquid is forced against the periphery of the drum while the gas is removed through the central withdrawal vapor passage. The pitot tube located near the drum periphery collects the high velocity liquid and pumps it through the recirculating brine loop. The vapor is drawn from the center of the rotating drum through a demistor. The vapor is then circulated in the cavity between the drum and the separator casing before being exhausted from the unit. The separator casing is insulated and maintained at a temperature above saturation by the heat from the motor.

Rotation of the drum is provided by a brushless dc motor through a magnetic coupling. The unit is statically sealed.

PERFORMANCE AND DESIGN REQUIREMENTS

Drum size, in.	6 dia x 4-1/4 long
High brine level, cc	800
Imersion level for pitot tube pickup, cc	100
Discharge brine flow rate, lb/hr	175 to 250
Brine and vapor temperatures, ^{0}F	40 to 150
Discharge brine pressure with 20 percent solids brine, drum speed of 1800 rpm, and brine flow of 202 lb/hr, psia	11
Discharge vapor flow rate, lb/hr	1.38
Discharge vapor pressure, psia	1.1

ITEM 208 (Continued)

Vapor passage pressure drop, in. H_2O	0.2 max
Drum speed, rpm	1800
Drum shaft power, watts	40 max
Input power with 28 ±4 vdc, watts	60 max
Weight, lb	10
Motor insulation resistance, megohms	50 minimum between terminals and case. 100 volts dc potential.
Motor dielectric voltage, volt rms	1500 and 2.0 milliamperes maximum leakage between terminals and case.
Proof pressure, psig	33
Burst pressure, psig	55

ITEM 210

VAPOR COMPRESSOR

PURPOSE

The compressor provides the vapor pressure rise necessary to assure the temperature differential needed for transfer of heat to the liquid brine by condensation of the vapor.

DESCRIPTION

The vapor compressor is a two-stage vortex compressor driven by a brushless dc motor. The rotor consists of two single sided impellers.

Compression is accomplished by imparting a velocity head to the vapor and then converting that velocity head into a pressure head. The vapor entering the compressor travels around the periphery of the impeller within a horseshoe-shaped stator channel. Within the channel, the vapor travels along helical streamlines with the centerline of the helix coinciding with the center of the curved channel. This helical flow pattern causes the gas to pass through the impeller buckets many times while it is passing through the compressor.

PERFORMANCE AND DESIGN REQUIREMENT

Inlet vapor pressure, psia	1.045
Inlet vapor temperature, ^{0}F	106.8
Pressure ratio	1.588
Vapor flow rate, lb/hr	1.38
Shaft speed, rpm	26,400
Shaft power, watts	55
Total input power with 28 ±4 vdc, watts	80
Proof pressure, psig	33
Burst pressure, psig	55
Motor insulation resistance, megohms	50 minimum between terminals and case with 100 volts dc potential.
Motor dielectric strength voltage, volt rms	1500 and 2.0 milliamperes maximum leakage between terminals and case
Weight, lb	8

ITEM 211

RECUPERATOR-REACTOR

PURPOSE

The unit purifies and sterilizes the vapor after it leaves the vapor compressor (210). Heating is accomplished within the recuperator section and oxidation of the trace contaminants is performed within the pyrolysis reactor section. Sterilization of the vapor is effected at the same time due to the high operating temperature of the catalyst bed.

DESCRIPTION

The unit consists of a high effectiveness recuperator and a pyrolysis reactor section containing an electrical heater and a catalyst. The recuperator has a tubular multipass cross-counterflow arrangement with multipassing accomplished on the shell side of the tube. The reactor catalyst is a series of stainless steel wire screen coated with rhodium.

Cool vapor enters the unit and flows through the shell side of the recuperator and into the reactor section. Within this section, the vapor is heated by an electrical heater. The vapor next flows through the catalyst where catalytic oxidation of the contaminants is accomplished. The catalyst bed consists of rhodium plated stainless steel screens. The hot vapor leaving the catalyst then flows back through the recuperator inside the tubes before leaving the unit. A redundant electrical heater is provided within the unit.

The recuperator and reactor are enclosed by a vacuum-jacketed outer shell. Within the vacuum enclosure are installed about 10 layers of foil radiation insulation separated by fiberglass sheets to reduce radiant heat loss.

PERFORMANCE AND DESIGN REQUIREMENTS

Flow rate, lb/hr	1.38
Inlet vapor pressure, psia	1.65
Pressure drop across unit, in. H_2O	2.6 maximum at flow of 1.38 lb/hr
Temperature, ^0F	
Cold side inlet	119
Hot side inlet	800
Hot side outlet	154

ITEM 211 (Continued)

Recuperator effectiveness	0.95 minimum
Reactor heater power, watts	25 (max) with 28 ±4 vdc input
Heat leak, Btu/hr	48.8
Weight, lb	5
Proof pressure, psig	33
Burst pressure, psig	55

ITEM 214

TEMPERATURE SENSOR

PURPOSE

This sensor measures the temperature in the pyrolysis reactor section of the reactor-recuperator unit (211) and provides the control signal to the temperature controller (215) which controls the electrical power input to the pyrolysis reactor heater. Two sensors are used in parallel to provide redundancy.

DESCRIPTION

The sensor is basically a resistance sensor with resistance change proportional to temperature change. The sensor forms the measured branch of a resistance bridge in the controller (215). The signal from this sensor is also used for display.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating temperature range, $^{\circ}F$	500 to 1000
Accuracy, $^{\circ}F$	± 10
Insulation resistance between terminals and sensor housing, megohms	100 minimum at 100 vdc
Dielectric voltage, vac (rms)	500 at 60 cps
Weight, lb	0.1

ITEM 215

TEMPERATURE CONTROLLER

PURPOSE

The temperature controller is used in conjunction with a temperature sensor (214) and the reactor heater to maintain the vapor within the pyrolysis reactor section of the reactor-recuperator unit (211) at 800°F. The controller converts a temperature error signal from an internal resistance bridge into a power signal for activating or deactivating the pyrolysis reactor electrical heater.

DESCRIPTION

The controller employs solid state components and basically consists of a resistance error bridge and a switching output power circuit. One branch of the bridge is formed by the external temperature sensor (214).

The controller supplies dc power to the heater when a difference exists between the reference temperature, 800°F, and the sensed vapor temperature. When the difference is essentially zero, dc power input to the heater is interrupted.

A high temperature limit circuit (900°F limit) is incorporated in the controller to prevent a continuous output power condition in the event of a failure of the switching circuit.

PERFORMANCE AND DESIGN REQUIREMENT

Control temperature, °F	800
Control range, °F	770 to 830
Upper temperature limit, °F	900
Output power, watts	30 maximum with 28 ±4 vdc
Input power, watts	40 maximum with 28 ±4 vdc
Weight, lb	0.6

ITEM 217

MANUAL SHUTOFF VALVE

PURPOSE

This valve is used in the vapor loop to isolate it from the brine loop. This valve is similar to the common -C valve except for line size.

DESCRIPTION

The valve contains a manually-operated poppet to restrict the flow through the unit. The poppet is integrally connected to a bellows that serves as a static and dynamic seal for preventing external leakage. A quarter turn of the handle is required to move the poppet from the full-closed position to the full-open position.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating pressure, psig	15 max across valve ports. Normal 0.5 psia with 5 psia cabin
Inlet temperature, $^{\circ}F$	40 to 150
Flow rate at 1.09 psia and $100^{\circ}F$ water vapor, lb/hr	1.38 at 0.1 in. H_2O maximum ΔP
Proof pressure, psig	33
Burst pressure, psig	55
Line size, inch	1/2
Operating torque, lb-in.	5
Weight, lb	0.7

ITEM 218

POWER SWITCH

PURPOSE

The switch allows activation of the vapor compressor (210) and the recuperator-reactor (211).

DESCRIPTION

The switch is a single-pole double-throw hermetically-sealed toggle switch with panel mounting provision.

PERFORMANCE AND DESIGN REQUIREMENTS

Voltage rating, volts dc	35 maximum
Current rating, amps	10 maximum
Type connector	PTIH Bendix type or MS equivalent
Weight, lb	0.1

ITEM 229

PRESSURE REGULATOR

PURPOSE

The unit controls the pressure in the water recovery loops by regulating the noncondensible gas vent pressure from the heater-condenser (206). It is used to control water reclamation rate.

DESCRIPTION

The unit contains an aneroid-operated metering valve which opens to vent noncondensible gases and water vapor to maintain a vent pressure between 0.5 and 2.5 psia. The vent pressure is selectable by means of a screw attached to the top of the aneroid element.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating fluid	Noncondensible gases (includes CO_2, CO, and O_2) and water vapor
Regulated pressure, psia	Selectable between 0.5 and 2.5
Maximum pressure, psia	14.7 psia external with 0.3 psia internal.
Flow rate, lb/hr	0.2 to 0.4
Leakage, sccm	2 sccm at vent pressure of 2.5 psia, discharge of 0.1 psia, and ambient pressure of 7 psia
Proof pressure, psig	23 external pressure
Burst pressure, psig	38 external pressure
Line size, in.	1/4
Weight, lb.	1

ITEM 230

BLEED VALVE

PURPOSE

This valve permits slow depressurization of the entire water reclamation unit upon startup. The rate of pressure decrease in the system is controlled at a very low value to prevent foaming (which would cause liquid entrainment) in the phase separator (208).

DESCRIPTION

The valve is a manually operated needle valve with flow capacity limited by an orifice builtin to the valve body. In the full open position valve flow will limit the vapor loop pressure decay to 0.5 psi per minute. When the desired operating pressure is reached the valve is closed and the condenser pressure regulator (229) is activated.

PERFORMANCE AND DESIGN DATA

Operating pressure, psia	0 to 14.7
Inlet temperature, ^{0}F	40 to 150
Proof pressure, psig	80
Burst pressure, psig	160
Line size, in.	1/4
Operating torque, in.-lb	5 max
Weight, lb	0.2

ITEM 233-D

QUICK-DISCONNECT

This item is identical to Item 113-D.

ITEMS 235 AND 236

DENSITY CONTROL SOURCE AND DETECTOR

PURPOSE

This sensor measures the solids concentration of the urine brine in the phase separator (208) and provides the control signal to the brine loop controller (239) which operates a brine dump solenoid valve (240) in the concentration control loop.

DESCRIPTION

The sensor consists of a shielded, low gamma emitting radiation source (235) and a radiation detector (236). The radiation source is Americium 241 and is mounted on one side of the separator housing. On the opposite side of the separator housing are located four Geiger Mueller (GM) tube detectors. The detector senses the variation in attenuation of gamma radiation caused by variation in the brine density. The count rate of the signal pulses from the GM tubes decreases as the brine concentration increases.

PERFORMANCE AND DESIGN REQUIREMENTS

Radiation source, millicuri	100 per source
Number of radiation source	One
Number of GM detector tubes	Four
Brine concentration range, percent of solids	17 to 50 normal. 3 to 60 maximum
Separator brine level, cc	100 to 800
Operating temperature, $^{\circ}F$	40 to 150
Accuracy, percent of solids concentration	± 2 at a constant brine level in the separator
Normal separator level, cc	750 cc
Approximate separation between radiation source and GM tubes, inches	5
Weight, lb	0.6

ITEMS 237 AND 238

LEVEL CONTROL SOURCE AND DETECTOR

PURPOSE

These items measure the level of the urine brine in the phase separator (208) and provide the control signal to the brine loop controller (239) which operates a feed control solenoid valve (240-B) in the level control loop.

DESCRIPTION

The sensor consists of a shielded, low gamma emitting radiation source (236) and a radiation detector (238). The radiation source is Americium 241 and is mounted on one side of the separator housing. On the opposite side of the separator housing is located a Geiger Mueller (GM) tube detector. This detector senses the variation in attenuation of gamma radiation caused by variation in the vapor-liquid interface and the brine density. When the liquid level increases, the count rate of the signal pulses from the GM tube decreases by a proportional amount.

PERFORMANCE AND DESIGN REQUIREMENTS

Radiation source, millicuri	30 per source
Number of radiation sources for level measurement	Two
Number of GM detector tube	One
Brine concentration, percent of solids	17 to 50 normal. 3 to 60 max
Separator brine level, cc	100 to 800
Operating temperature, ^{0}F	40 to 150
Output pulse from GM tube	Count rate equivalent to 140 to 440 cps corresponding to a separator level of 800 to 150 cc (inverse function). Refer to level controller calibration curve.
Accuracy, percent of level	±3 at a constant brine density
Approximate separation between radiation source and GM tube, inches	5
Weight, lb	0.4 total

ITEM 239

BRINE LOOP CONTROLLER

PURPOSE

This unit uses the signals from the separator density and level sensors to manage the fluid inventory in the brine loop. The controller activates the brine dump valve and the urine feed valves (240-B); also it provides power to the phase separator motor. The level sensor (237 and 238) also provides the controller with the inputs to signal valve (243) shut if the separator liquid level were to exceed a maximum limit.

DESCRIPTION

The controller basically employs amplifier-discriminator, integrator and comparator circuits to control the sequence for opening and closing the brine dump and urine feed valve in the following sequence.

The urine feed valve will be opened to maintain the separator level at 750 cc when the brine concentration is between 0 and 25 percent. When the brine concentration reaches 25 percent the urine feed valve will remain closed until the concentration increases to 50 percent. Brine level in the separator will then drop to about 280 cc. At that point the brine dump valve will open and remained opened until the separator level reaches its minimum operating level of 150 cc. The brine dump will then stop and the level controller will take command to refill the separator. The brine concentration in the loop will then be 17 percent. Cyclic operation between 17-25-50 percent then proceeds.

PERFORMANCE AND DESIGN DATA

Input signal from concentration controller, volts dc	0 to X proportional to 0 to 60 percent solids concentration. X is to be determined.
Input power with external feed control solenoid valve energized, watts	25 maximum at 28 ±4 vdc input
Output power to feed control solenoid valve, watts	6 maximum at 28 ±4 vdc
Operating temperature, °F	0 to 160
Weight, lb	3

ITEM 240-B

SOLENOID SHUTOFF VALVE

(SEE ITEM 107-B)

ITEM 241

BRINE STORAGE TANK

PURPOSE

The brine storage tank is used to store high concentration urine brine removed from the urine water recovery system. The tank is sized to hold the 90-day brine production (94.0 lb of 50 percent solids brine) before replacement.

DESCRIPTION

The tank is cylindrical and has a volume of 1.51 ft^3. The tank pressure is maintained lower than the brine pressure in the urine water recovery subsystem to allow removal of brine from the subsystem when the brine concentration reaches 50 percent. Nitrogen is used to pressurize the tank bladder.

PERFORMANCE AND DESIGN REQUIREMENTS

Storage capacity, ft^3	1.51 (max)
Tank gas pressure, psia	4
Brine temperature range, ^0F	70 - 150
Brine concentration, percent	50 - 55
Proof pressure (1.5 times max pressure of 110 psig), psig	165 on N_2 side 165 on brine side
Burst pressure (2.5 times max pressure of 110 psig), psig	275 on N_2 side 275 on brine side
Maximum inflow rate, lb/hr	5
Envelope, in.	12 1/2 dia x 28
Weight, lb	12 empty

ITEM 242

BRINE PRESSURE REGULATOR

PURPOSE

The unit regulates the gas pressure for waste brine tank pressurization. The tank pressure is controlled below that of the recirculating brine loop to insure the transfer of waste brine from the loop to the waste brine tank.

DESCRIPTION

The unit consists of an absolute pressure regulator vented to vacuum. The pressure regulator contains an aneroid-operated metering valve which maintains the brine tank pressure at 4 psia nominal.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating fluid	Gaseous nitrogen
Inlet pressure range, psig	85 to 115
Regulated pressure, psia	4 ±1
Flow, lb/hr	4 to 8 at inlet of 85 psia
Leakage (internal), sccm	2 at vent of 0.1 psia and sensed pressure of 6.0 psia
Proof pressure, psig	210 at inlet
Burst pressure, psig	350 at inlet
Line size, in.	1/4
Weight, lb	1

ITEM 243

SOLENOID SHUTOFF VALVE

This item is identical to item 240-B except that the valve is opened in the deenergized condition.

ITEM 301

pH SENSOR

PURPOSE

The unit senses the pH of the water drawn from the heater-condenser (206) prior to delivery to the reclaimed water tank. The sensor is used in conjunction with a signal conditioning circuit in the purity monitor unit (304) to provide signals for visual display and alarm equipment.

DESCRIPTION

The pH sensor is a combination probe containing a reference and sensing electrode which measures the hydrogen ion concentration in the reclaimed water. The sensing electrode consists of an internally sealed tube with a metallic electrode and an external tube containing electrolyte which contacts the electrode. The reference electrode is a silver-silver chloride element which is in contact with a reference solution of saturated potassium chloride. Basically, pH measurement is accomplished by measuring the potential developed between the reclaimed water sample and the potassium chloride solution.

PERFORMANCE AND DESIGN REQUIREMENTS

Reclaimed water flow, lb/hr	0.5 to 1.5
pH measurement range	4 to 10
Alarm activation limit, pH	Above 9 and below 5
Accuracy, percent of full scale	±3 over 4 to 10 pH range
Operating temperature, ^{0}F	40 to 150
Operating pressure, psia	0.3 to 15, 0.3 to 2.5 normal
Proof pressure, psig	23 with high pressure on outside of unit. Also 33 inside of unit.
Burst pressure, psig	38 with high pressure on outside of unit. Also 55 inside of unit
Weight, lb	0.2

ITEM 302

CONDUCTIVITY SENSOR

PURPOSE

This unit senses the specific conductance level of the water drawn from the heater-condenser (206) prior to delivery to the reclaimed water tank (308). The sensor is used in conjunction with a signal conditioning circuit in the purity monitor unit (304) to provide signals for visual display and the alarm equipment.

DESCRIPTION

Cylindrical metallic contacts are installed at each end of a non-metallic non-conducting tube in which the water flows. The contacts are wired to another toroidal pick up to complete the circuit. The only portion of the instrument in contact with the water is the non-metallic tube.

PERFORMANCE AND DESIGN REQUIREMENTS

Reclaimed water flow, lb/hr	0.5 to 1.5
Conductivity range, micromhos per cm	0 to 1000
Accuracy, percent of full scale	±3 over conductivity range
Operating temperature, ^{0}F	40 to 150
Operating pressure, psia	0.3 to 15, 0.3 to 2.5 normal
Alarm activation limit,	
Micromho per cm	Above 850
Micromho/cm-min	To be determined
Proof pressure, psig	23 with high pressure on outside of unit. Also 33 inside of unit.
Burst pressure, psig	38 with high pressure on outside of unit. Also 55 inside of unit.
Weight, lb	0.2

ITEM 303

ORGANICS MONITOR

PURPOSE

This instrument measures the total dissolved organics content of the reclaimed water.

DESCRIPTION

This item is an on-line instrument based on the ultraviolet absorption of organic compounds. It consists of a UV source and a monitor which measures the quantity of UV passing through the irradiated water stream. The output from the monitor is linear with the absorbance of ultraviolet radiation in the 254 millimicron wave length. The absorbance in turn is proportional to the dissolved organic content in the water.

PERFORMANCE AND DESIGN DATA

Reclaimed water flow, lb/hr	0.5 to 1.5
Operating temperature, ^{o}F	40 to 100
Operating pressure, psia	0.3 to 15
Proof pressure, psig	25
Burst pressure, psig	50
Weight, lb	1.0

ITEM 304

PURITY CONTROLLER

PURPOSE

The unit provides power to the pH sensor (301), conductivity sensor (302), and organics monitor (303) and conditions the output signal from the sensors for use in display meters for activation of the diverter valve (306), and activation of alarm circuits. The unit activates the diverter valve when the water quality is below the limit established for a particular parameter.

DESCRIPTION

The unit employs solid-state components. Voltage regulators, signal amplifiers, alarm circuits, and an output valve override circuit comprise the unit. Regulated dc signals are supplied to the interfacing sensors and the return signals are converted to appropriate waveshapes and amplified for use in remote display meters. Upon detection of any of the signals exceeding a level corresponding to substandard reclaimed water, the unit provides dc power to the remote diverter valve which diverts the water to a bypass circuit for reprocessing. Simultaneously, an alarm signal is applied to a warning light.

Display meters are provided on the unit to monitor pH, conductivity and organics content of the reclaimed water.

PERFORMANCE AND DESIGN REQUIREMENTS

Input power with zero output to warning light and diverter valve, watts	10 maximum with 28 ±4 vdc input
Input power with power applied to warning light and diverter valve, watts	17 maximum with 28 ±4 vdc input
Output voltage for display meters, volts dc	0 to 5 across 30K ohm load
Accuracy, percent of full scale	±2 over range of input signal
Output impedance of meter circuit, ohms	100 maximum
Warning and alarm circuit function	Grounds 28 vdc return side of warning light and alarm relay when poor water quality condition is detected
Weight, lb	2

ITEM 305

SILVER-ION GENERATOR

PURPOSE

The unit is installed between the water recovery heater-condenser (206) and the cyclic accumulator (313) to achieve effective sterilization of the water withdrawn from the condenser at the uniform flow rate.

DESCRIPTION

In operation, the silver-ion generator transports silver ions through the reclaimed water flowing through the generator. The microorganisms are killed by the germicidal properties of silver ions. Two silver electrodes are placed in the flow stream, and a potential is maintained across them by a silver-oxide battery. Silver ions are thus transported through the water from the silver anode to the silver cathode. A small quantity of silver is entrained by the water.

The body of the ion generator is of aluminum construction. Aluminum and silver form an electrolytic cell in which the silver becomes the positive electrode (anode). Both silver electrodes, i.e., anode and cathode, are electrically isolated from the aluminum system which is considered to be the ground, to prevent undesirable electrical currents, corrosion, and plating out of silver ions.

To avoid complete electrical isolation of the cell, the silver anode is grounded through a high resistance (22 megohm). The current which would normally flow from the silver anode to the aluminum ground is then effectively nulled by current flowing from the battery to the anode. Corrosion of the aluminum portions of the cell is inhibited, but the aluminum is maintained slightly anodic and tends to repel deposition or reduction of the ionic silver produced at the anode. By placing another resistor (22 megohm) in parallel with ammeter connections and/or a switch, a trickle current (about 0.2 μa) always flows between the anode and cathode and the condition of zero current flow between the anode and ground is maintained even if the cell is essentially in an off status. The cathode is completely insulated to avoid any contact with the ground. Cell design minimizes any interaction between the aluminum ground and the silver cathode.

A regulated small current drain is required for extended period up to one year. This dictates the use of a battery with a very stable voltage output. Flight units will be equipped with silver oxide battery (Union Carbide, Eveready No. 301, 100_mAH, 4.5 v). These batteries, rated at 100_mAH, will have a service life of more than one year under a continuous current drain of 10 μa.

ITEM 305

PERFORMANCE AND DESIGN REQUIREMENT

Flow capacity	3 to 12 cc/min with 7.6 cc/min nominal rate
Normal operating pressure	0.3 to 2.5 psia with 5 to 7 psia external pressure
Maximum pressure	15 psia external and 0.3 psia internal
Battery voltage	4.5 volts
Battery average current	To be determined
Operating temperature	40 to 150°F
Proof pressure	23 psig external pressure. Also 33 psig internal pressure.
Burst pressure	38 psig external pressure. Also 55 psig internal pressure.
Weight	0.7 lb

ITEM 306

DIVERTER VALVE

PURPOSE

This valve is used in conjunction with the water purity controller (304) to prevent contaminated reclaimed water from flowing to the reclaimed water tanks. When energized, the valve directs the flow of contaminated water to the urine supply tank for reprocessing.

DESCRIPTION

The valve has one inlet and two outlet ports. Liquid flow is from the inlet to either one of the outlet ports. Switching from one outlet port to the other is accomplished by a solenoid actuated device.

In the normal mode of operation, the valve is spring-loaded in a position that allows water flow to the reclaimed water tank. Power is automatically supplied to the valve by the alarm-controller when a contaminated water condition is detected.

PERFORMANCE AND DESIGN REQUIREMENTS

Effluent	water
Flow rate, lb/hr	150 lb/hr at 0.5 psi maximum ΔP
Inlet pressure, psig	37 max
Operating power (28 ±4 vdc input), watts	6 maximum
Operating temperature range, ^{0}F	40 to 150
Proof pressure, psig	56
Burst pressure, psig	93
Weight, lb	0.8

ITEM 307-E

BACTERIA FILTER

(SEE ITEM 115-E)

ITEM 308

RECLAIMED WATER STORAGE TANK

PURPOSE

The reclaimed water tank is used to store water condensate obtained directly from the urine water recovery subsystem. Two tanks are used; one tank is used for bacterial testing while the second tank is used for receiving and checking the water production rate. Each tank is sized for storage of 20 lb of water.

DESCRIPTION

The tank is cylindrical and has a usable volume of 0.33 ft^3. Expulsion of water is provided by a bladder pressurized with 30 psig (relative to cabin pressure) nitrogen. When the tank is filled, the bladder is fully collapsed.

PERFORMANCE AND DESIGN REQUIREMENTS

Storage capacity, ft^3	0.33
Storage capacity, lb	20
Expulsion gas pressure, psig	28 to 32
Expulsion gas relief pressure, psig	37
Maximum pressure due to open failure of pressure regulator, psig	110
Water temperature range, ^0F	40 to 150
Proof pressure (1.5 times max press of 110 psig)	
Water side, psig	165
Nitrogen side, psig	165
Burst pressure (2.5 times max press of 110 psig)	275 psia
Weight, lb	6 lb empty
Max inflow rate, lb/hr	4

ITEM 309

MANUAL SHUTOFF VALVE

(SEE ITEM 112-C)

ITEM 310-A

CHECK VALVE

(SEE ITEM 106-A)

ITEM 311-D

QUICK-DISCONNECT

(SEE ITEM 113-D)

ITEM 312

PRESSURE REGULATOR-RELIEF

PURPOSE

The unit provides regulated nitrogen pressure to the reclaimed water tank (308) for positive expulsion and transfer of the reclaimed water spacecraft water supply. A relief valve is incorporated to prevent overpressurization of the reclaimed water tank.

DESCRIPTION

The unit consists of a differential pressure regulator and a relief valve. The pressure regulator contains a normally-open, diaphragm-operated poppet metering valve. As pressure is applied to the normally-open valve, the downstream pressure of the valve is sensed across the diaphragm which throttles the metering valve to maintain the downstream pressure at 30 ±2 psig (relative to cabin).

The relief valve is located in the outlet chamber of the unit. It vents excess pressure into the cabin to limit downstream pressure to 35 ±2 psig (relative to cabin pressure). Operation of the relief valve is similar to that of the pressure regulator except that the valve is normally closed.

PERFORMANCE AND DESIGN REQUIREMENTS

Operating fluid	Gaseous nitrogen
Inlet pressure range, psia	85 to 115
Regulated outlet pressure, psig	30 ±2
Flow	6 to 10 lb/hr at inlet of 85 psia
Relief pressure, psig	35 ±2
Regulator leakage	10 sccm at inlet of 115 psia and outlet of 32 psig
Proof pressure, psig	210 at inlet
Burst pressure, psig	350 at inlet
Line size, in.	1/4
Weight, lb	1

ITEM 313

CYCLIC ACCUMULATOR

PURPOSE

The cyclic accumulator removes condensate from the water recovery heater-condenser (313) and expels the collected liquid to the reclaimed water tank (308) if the water quality is acceptable, or to the urine storage tank (201) if the water is contaminated.

DESCRIPTION

The cyclic accumulator is a pneumatically-operated reciprocating pump. Two check valves in series are located at the water inlet and outlet ports to prevent high pressure reverse water flow. Water is periodically expelled from the accumulator by nitrogen gas pressure applied to a spring loaded, elastic bellows assembly. At the end of an expulsion cycle, the nitrogen gas supply is shut off and the residual gas in the accumulator is discharged through a bleed orifice to vacuum. This allows the spring-loaded bellows to move in the reverse direction, drawing water into the accumulator through the inlet check valve. The movement of the bellows creates a differential pressure across the hydrophylic separator plate within the heater-condenser to cause water to flow out of the heater-condenser into the cyclic accumulator.

PERFORMANCE AND DESIGN REQUIREMENTS

Inlet nitrogen pressure, psia	55 to 87 with a 5 psia cabin
Inlet nitrogen flow, lb/min	0.05 maximum with 85 psia and 70°F inlet with bellows spring initially in extended position
Nitrogen flow cycle	Nitrogen flow every 10 ±1 min. for a duration of 10 ±1 sec
Discharge nitrogen pressure, psia	Less than 0.2
Nitrogen bleed orifice flow, lb/hr	0.55 at 87 psia cyclic accumulator pressure and 0.1 psia discharge pressure
Water side capacity, cc	130 to 150
Maximum water side ullage, cc	10
Inlet water flow, cc/min	3 to 12 with 7.6 nominal rate

ITEM 313 (Continued)

Inlet water pressure, psia	0.3 to 2.5 psia
Outlet water flow, lb/hr	100 max during expulsion with 85 psia nitrogen pressure
Outlet water pressure, psia	35 ±2 normal, 42 maximum
Fitting, inch	1/4 for water and nitrogen
Proof pressure, psig	Nitrogen side 210 with water side at 30. Water side 56 with N_2 side at 0.
Burst pressure, psig	Nitrogen side 350 with water side at 30. Water side 93 with N_2 side at 0.
Weight, lb	2

ITEM 314-B

SOLENOID VALVE

(SEE ITEM 107-B)

ITEM 315

CYCLIC ACCUMULATOR TIMER-CONTROLLER

PURPOSE

The timer-controller regulates the operational cycle of the cycle accumulator (313) by supplying power to the cyclic accumulator valve assembly (314-B) at predetermined intervals.

DESCRIPTION

The unit basically contains a timing circuit and a power switching circuit. The timing circuit regulates the duration of the power-on and power-off portion of the operational cycle. The output of the timing circuit is supplied to the switching circuit which is used to energize the cyclic accumulator valve assembly (314-B).

PERFORMANCE AND DESIGN REQUIREMENTS

Output power-on duration, seconds	10 ±1
Output power-off duration, minutes	10 ±1
Input power at 28 ±4 vdc, watts	5 maximum
Output power at 28 vdc, watts	3 maximum
Voltage drop between input and output during on condition, volt	0.5 max
Weight, lb	0.5

ITEM 401

URINE STORAGE QUANTITY METER

PURPOSE

The unit measures the quantity of liquid contained in the urine supply tank (201) and produces a proportional output signal for a visual display.

DESCRIPTION

The unit consists of a potentiometer assembly and a signal conditioning circuit comprised of a solid-state component. The movable part of the potentiometer assembly is attached to the pressurization bladder in the urine supply tank. The stationary part of the assembly is attached to the bladder support frame. The potentiometer section measures the bladder position which is proportional to the liquid content.

The potentiometer resistance forms one branch of a resistance bridge in the signal conditioning circuit. When the resistance bridge is electrically unbalanced, the measurement unit provides an output signal for visual display.

The meter is a jewel-mounted galvanometer movement operating between the 0 to 5 vdc full range input supplied by the quantity measurement unit. The movement is mounted in a case that allows replaceable panel mounting. The readout is calibrated in lb.

PERFORMANCE AND DESIGN REQUIREMENTS

Transducer

Sense quantity range, lb	0 to 40
Operating temperature, ^{0}F	40 to 150
Output signal, volts dc	0 to 5.0 proportional to quantity range of 0 to 33 lb. 5.5 maximum
Accuracy, percent of full scale	±10 over full range of sense quantity in tank
Input voltage, volts dc	28 ±4
Input current, milliamperes	40 maximum
Output ripple component of output signal, millivolts rms	5 maximum
Output impedance, ohms	100 maximum

ITEM 401 (Continued)

Output load resistance, ohms	30,000 nominal
Isolation resistance between power input and signal output, megohms	100 minimum at 100 vdc across power input (+) and signal output (-)
Insulation resistance between terminals and case, megohms	50 minimum at 100 vdc
Weight, lb	0.4

Meter

Input voltage, volts dc	Normal, 0 to 5. Maximum 5.5.
Meter face calibration, lb	0 to 33 corresponding to 0 to 5 vdc input. Readout is proportional to input
Accuracy, percent of full scale	±3 throughout full scale range
Meter resistance load, ohms	30,000 nominal
Weight, lb	0.3

ITEM 402

URINE STORAGE PRESSURE TRANSDUCER

PURPOSE

The pressure transducer measures the pressure in the urine storage tank (201) and produces a proportional output signal for a visual display meter.

DESCRIPTION

The unit employs a variable reluctance pickup in close proximity to the movable sensing element. When pressure is applied to the sensing port, the sensing element is deflected a proportional amount. This deflection causes an electrical unbalance in the variabel reluctance pickup and the resulting signal is conditioned within an integral signal conditioning circuit to provide an output signal for visual display and telemetry functions.

The meter is a jewel-mounted galvanometer movement operating between the 0 to 5 vdc full range input supplied by the pressure transducer. The movement is mounted in a case that allows replaceable panel mounting. The readout is calibrated in psig.

PERFORMANCE AND DESIGN REQUIREMENTS

Transducer

Sense pressure range, psig	0 to 8
Fluid	Nitrogen
Operating temperature, ^{0}F	40 to 150
Output signal, volt dc	0 to 5 proportional to applied sense pressure
Maximum output signal, volt dc	5.5
Accuracy, percent of full scale	±3 over full range of applied sense pressure
Input voltage, volts dc	28 ±4
Input current, milliamperes	30 maximum
Output ripple, component of output signal, millivolts rms	5 maximum
Output impedance, ohms	100 maximum

ITEM 402 (Continued)

Output load resistance, ohms	30,000 nominal
Proof pressure, psig	60
Burst pressure, psig	100
Isolation resistance between power input and signal output, megohms	100 minimum at 100 vdc across power input (+) and signal output (-)
Insulation resistance between terminals and case, megohms	50 minimum at 100 vdc
Weight, lb	0.5

Meter

Input voltage, volts dc	Normal, 0 to 5. Maximum, 5.5
Meter face calibration, psig	0 to 40 corresponding to 0 to 5 vdc input
Accuracy, percent of full scale	±3 throughout full scale range
Meter resistance load, ohms	30,000 nominal
Weight, lb	0.3

ITEM 403

BRINE STORAGE QUANTITY METER

This unit is identical to Item 401 but for its range. The brine storage quantity meter sense quantity range is 0 to 110 lb.

ITEM 404

BRINE STORAGE PRESSURE TRANSDUCER

(SEE ITEM 402)

ITEM 405

RECLAIMED WATER QUANTITY METER

This unit is identical to Item 401 but for its range. The range capability requirement is 0 to 20 lb.

ITEM 406

RECLAIMED WATER STORAGE PRESSURE METER

This unit is identical to item 402 except for its range. The range of item 406 is 0 to 40 psig.

ITEM 407

PRETREATMENT TANK QUANTITY METER

This unit is identical to Item 401 except for its range which is from 0 to 7 lb.

ITEM 409

AMMETER

PURPOSE

The ammeter measures the current demand of the system motors and provides visual display. Four instruments are installed on the system for monitoring of motor performance. In the urine collection circuit on the separator (101) and blower (103) motors, and in the reclamation unit on the separator (208) and the compressor (210) motors.

DESCRIPTION

The ammeter employs a jewel-mounted galvanometer movement and a current shunt to measure and display the current in amperes.

PERFORMANCE AND DESIGN REQUIREMENTS

Input dc current, amperes	1.5 to 2 normal
Meter range, amperes	0 to 4.0
Accuracy, percent of full scale	±5
DC voltage	28 ±4
Insulation resistance between terminals and case, megohms	50 minimum at 100 vdc
Weight, lb	0.5

ITEM 410

TEMPERATURE SENSOR

PURPOSE

The sensor measures the brine temperature at the outlet of the phase separator (208) and provides an output signal to a remotely located signal conditioner which conditions the signal for a display meter.

DESCRIPTION

The sensor consists of a resistance-wire type sensing element and a resistance-bridge circuit. The sensing element forms one branch of the resistance bridge. A change in sense temperature from a reference value unbalances the resistance bridge causing it to produce an output signal for the signal conditioner. The sensor is mounted externally on the brine tube and suitably insulated from ambient. In this manner it can be replaced without opening the brine loop or interrupting operation.

The signal conditioner employs solid-state components and provides power to the temperature sensor. The return signal from the sensor is conditioned and applied to the temperature meter.

The meter is a jewel-mounted galvanometer movement operating between the 0 to 5 vdc full range input supplied by the signal conditioner. The movement is mounted in a case that allows replaceable panel mounting. The readout is calibrated in ^{0}F.

PERFORMANCE AND DESIGN REQUIREMENTS

<u>Sensor</u>

Sense temperature range, ^{0}F	50 to 130
Operating temperature, ^{0}F	40 to 150
Operating pressure, psia	10 to 11 normal, 1 to 15 range
Resistance range of sensing element, ohm	to be determined
Accuracy of sensor, percent of full scale	±1.5 throughout 0 to 100 percent of input temperature range
Input signal	to be determined
Output signal	to be determined

ITEM 410 (Continued)

Power dissipation of sensing element, milliwatts	
Time constant, seconds	4 max to 63.2 percent of step change in water temperature
Proof pressure, psig	33
Burst pressure, psig	55
Weight, lb	0.1

Signal Conditioner

Output signal, vdc	0 to 5 proportional to input signal. 5.5 maximum
Accuracy, percent of full scale	±1.5 throughout 0 to 100 percent of input
Output impedance, ohms	100 maximum
Output load resistance, ohms	30,000 nominal
Input supply voltage, vdc	28 ±4
Input supply current, milliamperes	40 maximum with 28 ±4 vdc input
Isolation resistance between power input and signal output, megohms	100 minimum at 100 vdc across power input (+) and signal output (-)
Insulation resistance between terminals and case, megohms	50 minimum at 100 vdc
Weight, lb	0.3

Meter

Input voltage, volts dc	Normal, 0 to 5. Maximum, 5.5
Meter face calibration, ^{0}F	80 to 130 corresponding to 0 to 5 vdc input
Accuracy, percent of full scale	±3 throughout full scale range
Meter resistance load, ohms	30,000 nominal
Weight, lb	0.3

ITEM 411

SEPARATOR PRESSURE

This unit is similar to Item 402; its range, however is different (0.2 to 3.0 psia).

ITEM 412

BRINE TEMPERATURE-CONDENSER OUTLET

(SEE ITEM 410)

ITEM 413

CATALYTIC REACTOR TEMPERATURE

This unit is similar to Item 410 with an operating temperature range between 600 and $1000^{\circ}F$.

ITEM 414

CONDENSER PRESSURE

(SEE ITEM 411)

APPENDIX B

PERFORMANCE PREDICTION COMPUTER PROGRAM DESCRIPTION

INTRODUCTION

Because of the complexity of the IWRS processing system, manual performance predictions are very time consuming. Since it was desired to examine system performance over a range of operating parameters, and with several candidate component configurations, computer simulation of the performance seemed appropriate. A computer program to simulate system performance at any set of operating parameters has been developed. This Appendix presents a description of the program.

Included in this description is a discussion of the analytical technique used to model the system and component performance, block diagrams of the main program and subroutines, and listings of these programs. Also given is a discussion of the input data, the utility and data routines, and the program outputs.

PROGRAM SCOPE

This program was developed to characterize the performance of the IWRS main processing unit. This includes the following major elements of the IWRS:

- Compressor
- Separator
- Condenser
- Flash Valve
- Recuperator
- Catalyst Bed
- Interconnecting Lines

The feed supply system, the brine dump system, and the product water system are not included in the program analysis. Specific operational cycling of the control system is likewise not included; however, the net energy balance of the system includes the effect of feed urine into the brine loop. The program performs a steady-state solution of the system performance at a given set of conditions.

SYSTEM AND COMPONENT CHARACTERIZATIONS

General

Determination of the performance of the IWRS involves conducting a net energy balance on the brine loop. This balance is given as

$$\Sigma Q = W_B C_{pB} \Delta T_B \tag{1}$$

where ΣQ = the summation of heat gained or lost by the brine loop in all the elements of the loop

W_B = brine flow rate

C_{pB} = brine specific heat

ΔT_B = brine change in temperature

Figure B-1* is a schematic of the IWRS processing loop, giving the designation of system state points and system elements used in the computer program. From this it can be seen that the temperature difference across the flash valve, $T_1 - T_5$, will determine the amount of water vaporized. Thus

$$W_V = \left[C_{pB}\ W_B\ (T_1 - T_5) + P_8 - Q_{L8}\right] / \Delta H_{LV} \tag{2}$$

where W_V = vapor flow rate from separator

P_8 = power dissipated in separator

Q_{L8} = heat leak from separator

ΔH_{LV} = heat of vaporization of water from the brine.

The analysis of all the elements of the system is accomplished to permit computation with the energy balance shown above.

The following paragraphs give the analytical methods used in each of the component analysis subroutines.

Fluid Flow in Interconnecting Lines

Flow of brine in the brine loop, and vapor in the vapor lines is characterized by the following relation:

$$\Delta P = \frac{2\ f\ w^2}{\pi^2\ D^5\ \rho} \tag{3}$$

---

*All figures have been placed at the end of this appendix.

where w = flowrate

D = tube diameter

ρ = density

f = friction factor

The friction factor is a function of Reynolds number and is given in Figure B-2. The heat loss from these lines is given by

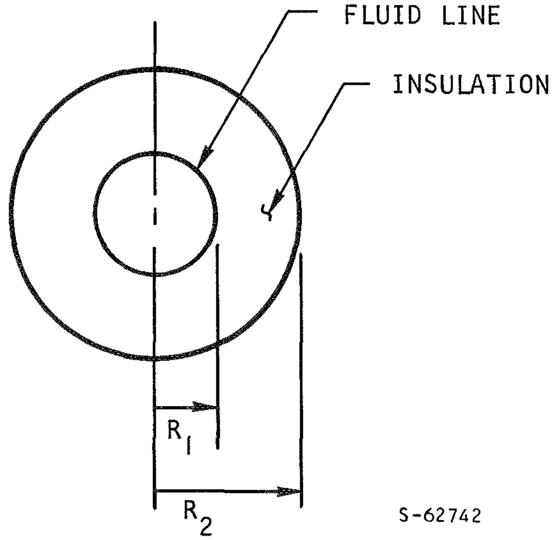
$$Q_L = UA\,(T - T_A) \tag{4}$$

where T = temperature of line

T_A = ambient temperature

UA = heat transfer coefficient times area of lines

Some of the lines, notably the vapor lines, are insulated, while the brine lines are uninsulated. For the former case, UA is evaluated as follows (see sketch):



Heat transfer through the insulation is given by

$$q = \frac{2\pi KL(T-T_o)}{\ln\,(R_2/R_1)} \tag{5}$$

where K = thermal conductivity of insulation

L = line length

T_o = temperature of outer surface of insulation

Heat transfer from the outer surface of insulation is given by

$$q = h_2 \pi R_2 L(T_o - T_A) \tag{6}$$

where h_2 = external heat transfer coefficient

Combining Equations (5) and (6) yields the following:

$$UA = 1/\left(\frac{1}{2\pi R_2 L h_2} + \frac{\ln(R_2/R_1)}{2\pi K L}\right) \tag{7}$$

For lines with no insulation, only the first term of the denominator of Equation (7) applies.

Separator

The output pressure of the separator is evaluated from the following equation:

$$P = \frac{1}{2}(1-K)^2 \rho R^2 \Omega^2 \tag{8}$$

where Ω = rotational speed

R = pitot tube radius

ρ = brine density

K = head coefficient

The head coefficient K is a function of Reynolds number of the pitot tube in the brine and has been determined experimentally as:

$$K = 0.728/(R_e)^{0.15}$$

R_e = Reynolds number

In a similar manner, the drag of the pitot tube is given by:

$$D = \frac{1}{4} C \rho \Omega^3 (R^4 - R_L{}^4) \tag{9}$$

where R_L = liquid surface radius

C = drag coefficient

$$C = 0.756/(R_e)^{0.16}$$

Heat transfer to ambient is calculated in a manner similar to that used for heat leak from the lines.

Compressor

The compressor performance is determined from experimental data in the form of pressure ratio and power versus volumetric inlet flow. The performance curves used in the system analysis are given in Section 3 of this report. The power of the compressor is then corrected to the operating pressure by

$$W = W_B \frac{P}{P_B} \tag{10}$$

where W_B = power at inlet pressure P_B

P = inlet pressure

Compressor efficiency is given by

$$\eta = (100)W_A/W \tag{11}$$

where W_A = adiabatic power required

$$W_A = \frac{P_I V_I}{\left(\frac{\gamma - 1}{\gamma}\right)} \left[\left(\frac{P_o}{P_I}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] \tag{12}$$

where P_I = inlet pressure

P_o = outlet

V_I = inlet volumetric flow

γ = specific heat ratio cp/cv

Condenser

The heat transfer process in the condenser is represented by

$$Q = UA\ (T_S - T_B) \tag{13}$$

where T_S = condensing temperature

T_B = Brine temperature

UA = overall heat transfer coefficient

with

$$UA = 1/\left(\frac{D_o}{D_I\ H_B} + \frac{1}{H_S} + f + \frac{D_o\ \ln D_o/D_I}{2\ K}\right) \qquad (14)$$

where D_o = tube outer diameter

D_I = tube inner diameter

H_B = brine side heat transfer coefficient

H_S = steam side heat transfer coefficient

f = tube fouling factor

K = tube thermal conductivity

$$H_B = \frac{4.\ w_B\ C_{pB}\ J}{\pi\ D_I^{\ 2}\ P_R^{\ 2/3}} \qquad (15)$$

where w_B = brine flow rate

C_{pB} = brine specific heat

P_R = Prandtl number

Figure B-3 gives J versus Reynolds number for the heat exchanger tube. The condensing heat transfer coefficient is given by

$$H_S = 0.725\left[\frac{\rho\ g\ h_{fg}\ k^3}{\mu\ D_o(T_S-T_w)}\right]^{1/4} \qquad (16)$$

where ρ = water density

g = 32.2 ft/sec^2

h_{fg} = heat of vaporization of water

k = thermal conductivity of water

μ = viscosity of water

T_w = tube wall temperature

The vapor and brine pressure drop is calculated using the same formula given above for pressure drop in a tube. Heat transfer from the condenser to ambient is likewise calculated as given above for the transfer lines.

Recuperator and Catalyst Bed

The configuration of the recuperator for which the program is designed is shown in Figure B-4. As indicated, the unit is a shell-tube recuperator with a wire mesh catalyst bed at the hot end. An electrical heater is assumed to be imbedded in the catalyst bed. The heat transfer coefficient for the recuperator is given by

$$H = \frac{J\ G\ C_p}{P_R^{\ 2/3}} \qquad (17)$$

where G = mass velocity = w/A

A = minimum flow area

w = flow rate

The values of J are shown in Figure B-5 for flow outside and inside the tubes. The pressure drop in the recuperator is given by

$$\Delta P = \frac{G^2}{2}\ v_n\ (1-\sigma^2)\ \left(\frac{v_o}{v_I} - 1\right) + f\ \frac{A}{A_c}\ \frac{v_v}{v_I}\ N_P \qquad (18)$$

for flow over the outside of the tubes

where v_n = mean specific volume

v_o = outlet specific volume

v_I = inlet specific volume

σ = free flow to frontal area ratio

f = friction factor

A = tube surface area

A_c = minimum free flow area

N_P = number of passes over tube bundle

and by

$$\Delta P = \frac{G^2\ v_n\ f}{2\ D_o} \qquad (19)$$

for flow inside the tubes.

A correction for flow across the baffles is also used, and is given by

$$\Delta P = 3.54G^2 \ v_n \ N_B \tag{20}$$

where N_B = number of baffles

Values of the friction factor f are given in Figure B-6 for flow inside and over the tubes. Pressure drop in the catalyst bed is given by

$$\Delta P = \frac{1}{2} G^2 v \ f \frac{A_w}{A_c} \tag{21}$$

where A_w = total surface of the catalyst

A_c = minimum fill flow area through the bed

The friction factor for the catalyst bed is given in Figure B-7. The Reynolds number used in the catalyst screen pressure drop calculations is given by

$$R_e = \frac{2 \ R_n \ G}{\mu} \tag{22}$$

where $R_n = (V_B - V_w)/A_w$

μ = viscosity

V_B = volume of catalyst bed

V_w = volume of wire in screen

A_w = area of wire in screen

The effectiveness of the recuperator is calculated by the following relation:

$$E = 1 - \frac{1}{1 + NTU \left(1 + \lambda\sqrt{\frac{\lambda NTU}{1+\lambda NTU}}\right) /(1+\lambda NTU)} \tag{23}$$

where NTU = number of transfer units

λ = axial conduction coefficient

NTU and λ are defined as follows:

$$NTU = UA/w \ C_p \tag{24}$$

where $UA = \dfrac{A}{\dfrac{1}{A_I} + \dfrac{1}{H_o} + \dfrac{t}{K}}$

A = tube area

t = tube wall thickness

K = thermal conductivity of tube

$$\lambda = \frac{K\ A_K}{Lw\ C_P} \qquad (25)$$

L = tube bundle length

A_K = conduction area in longitudinal direction

Heat leak to ambient is calculated as before with the other components.

FLUID PROPERTIES

In order to perform the calculations indicated by the above analyses, the thermodynamic and transport properties of the brine and water vapor are required. The following give the methods used in the computer program to obtain these properties.

Brine Properties

The vapor pressure and the viscosity of the brine as a function of concentration and temperature is shown in Figures B-8 and B-9. These data are interpreted in the program by a map-read subroutine. Other properties of the brine solution are determined as follows:

Density:

$$\rho = 62.43\ (0.99325 + 0.4775C),\ \text{lb/ft}^3 \qquad (26)$$

C = concentration, percent solids

Specific heat:

$$cp = 1.0 - 0.7C,\ \text{Btu/lb}\ ^oF \qquad (27)$$

Thermal conductivity:

$$K = 0.347\ \left[1.0 - 0.0015\ (T-100)\right]\ (1.0 - \frac{0.576C}{1.69-C}),\ \text{Btu/hr ft}^oF \qquad (28)$$

The heat of vaporization of water from the brine solution is determined from the heat of vaporization of water and the boiling point data given in Figure B-8. Figure B-10 gives the heat of vaporization of water over the range of temperature of interest in this system. The heat of vaporization of water from brine is given by

$$H = H^* \frac{\ln(P_2/P_1)}{\ln(P_2^*/P_1^*)}$$

where subscripts 1 and 2 refer to two state points separated by a small temperature difference and

P_1 = vapor pressure of urine

P_1^* = vapor pressure of water at same temperature

H^* = heat of vaporization of water

The above relations are sufficiently accurate over the range of temperature and concentration encountered in the IWRS. They are also used to determine the properties of water by setting the concentration equal to zero.

Steam Properties

The thermodynamic and transport properties of steam are determined as follows:

Density:

$$\rho = \frac{P}{RT}(144), \ \text{lb/ft}^3 \tag{29}$$

P = pressure, psia

T = absolute temperature, ^{0}R

R = gas constant for water, 85.8 lb_F-ft/lb_M ^{0}R

Specific heat:

$$C_p = 0.46 + 0.048\ (T-300)/700, \ \text{Btu/lb}\ ^0\text{F}$$

T = degrees F

Thermal conductivity:

$$K = \left(9.2 + \frac{25.5(T-32)}{968}\right) 10^{-3}, \ \text{Btu/hr ft}\ ^0\text{F}$$

Viscosity:

$$\mu = \left(1.81 + 0.0089T^{0.88}\right) 10^{-7}\ \frac{(3600)}{32.2}, \ \text{lb}_M\text{/ft-hr}$$

ROUTINE DISCRIPTIONS

Main Program URECV

The main program for the IWRS system analysis is URECV. This program provides the following functions:

Input of program data

Control of primary system convergence parameters

Transfer of data to the subroutines as required

Determination of system output requirements

This routine by itself performs no performance analysis. Figure B-11 is a block diagram of this program. Figure B-12 is a listing of URECV.

Subroutine SEPR

This subroutine is used to calculate the performance of the phase separator. The inputs to the program from URECV are as follows:

Brine volume

Brine concentration

Separator vapor pressure

From these, and other input data on configuration, SEPR determines the following:

Separator temperature

Separator heat leak

Separator power

Brine outlet pressure

Figures B-13 and B-14 are a block diagram and a listing of SEPR, respectively.

Subroutine PDVAP

This subroutine is used to calculate the pressure drop of each segment of the vapor lines. Inputs to the subroutine are the line segment inlet conditions, pressure, temperature, and flow rate. Outputs from SEPR are the line segment end point conditions, pressure and temperature, and the line segment heat leak. Figures B-15 and B-16 are a block diagram and a listing of this program.

Subroutine COMPR

Subroutine COMPR determines the performance of the compressor based on inlet conditions. Outputs from COMPR are outlet pressure and temperature, power, heat transfer to ambient, and compressor temperature. Figures B-17 and B-18 are a block diagram and listing of COMPR.

Subroutine RECUP

Subroutine RECUP determines the performance of the recuperator/catalyst bed. The outputs of this program are:

Outlet temperature and pressure

Effectiveness

Power

Heat leak

Pressure drops

A block diagram for RECUP is shown in Figure B-19. Figure B-20 is a listing of RECUP.

Subroutine CONDR

Subroutine CONDR is used to calculate the performance of the condenser. This routine determines the heat transfer to the brine, the brine temperature change, the vapor pressure drop, and the condenser heat leak. A block diagram and listing of this subroutine are given in Figures B-21 and B-22, respectively.

Subroutines BFLOW and BTEMP

Subroutines BFLOW and BTEMP are used to calculate the flow in the brine loop (BFLOW), and the temperature at various points in the loop (BTEMP). BTEMP also calculates the heat leak from each element of the loop and also accounts for the energy balance needed during feeding into the system and/or operation of the trim or warmup heater. Figures B-23 and B-24 give block diagrams and listing for BFLOW. Figures B-25 and B-26 give this information for BTEMP.

Subroutine PRINTT

This subroutine contains all of the format information to output the desired program parameters. Figures B-27 and B-28 give a flow diagram and a listing of this routine.

Utility Routines

Several utility routines are used in this program to perform operations of data storage and retrievals. UREAD is used to read in heat of vaporization of water, and vapor pressure and viscosity of brine. Figure B-29 is a listing of this routine. MAPRDP is used to determine brine viscosity or vapor pressure for a given temperature and concentration by interpolation of the data read in by UREAD. This routine can also determine boiling temperature at a given concentration and vapor pressure. Figure B-30 is a listing of this program. LAGIN2, Figure B-31, is an interpolation routine used to read all of the single independent variable data curves. It is used to interpolate all of the friction factor and J factor curves, as well as the heat of vaporization curve.

INPUT FORMAT

Table B-1* shows the input parameters for the system performance program. These parameters are defined in Table B-2. The inputs are grouped into three primary groupings:

(a) Fluid properties data

(b) System configuration data

(c) System operating parameters

The program control is set up to allow variations of the system operating parameters without repeating the system configuration data. Likewise, the system configuration data can be changed without repeating the fluid properties data.

OUTPUT FORMAT

Figure B-32 is a sample output of this program. The output is arranged in two parts as follows:

Part 1. - System and component configuration data (Inputs)

Part 2. - A. System operating parameters (Inputs)
B. System performance parameters (Outputs)

Part 1, configuration data, gives the physical parameters of the system. These are, for the most part, self-explanatory. However, a few require some definition.

*Tables appear following the figures at the end of this appendix.

(a) Separator

"Heat leak to ambient" is the term UA by which the heat leak is calculated.

$$Q_L = UA\ (T - T_{amb})$$

"Minimum Separator Volume" is the volume, calculated in the program, at which the pitot tube is just covered.

(b) Compressor

The listed parameters "Flow," "Pressure Ratio," and "Power" define the performance of the compressor. The power listed does not include bearing losses which are calculated separately in the program.

(c) Recuperator

"Flow Area on Shell Side" is the minimum flow area through the tube bundle per pass. "Frontal Area on Shell Side" is the total area of the tube bundle per pass.

"Axial Conduction Area" and "Axial Conduction Conductivity" are the parameters used to determine the effect of axial conduction on the effectiveness of the recuperator.

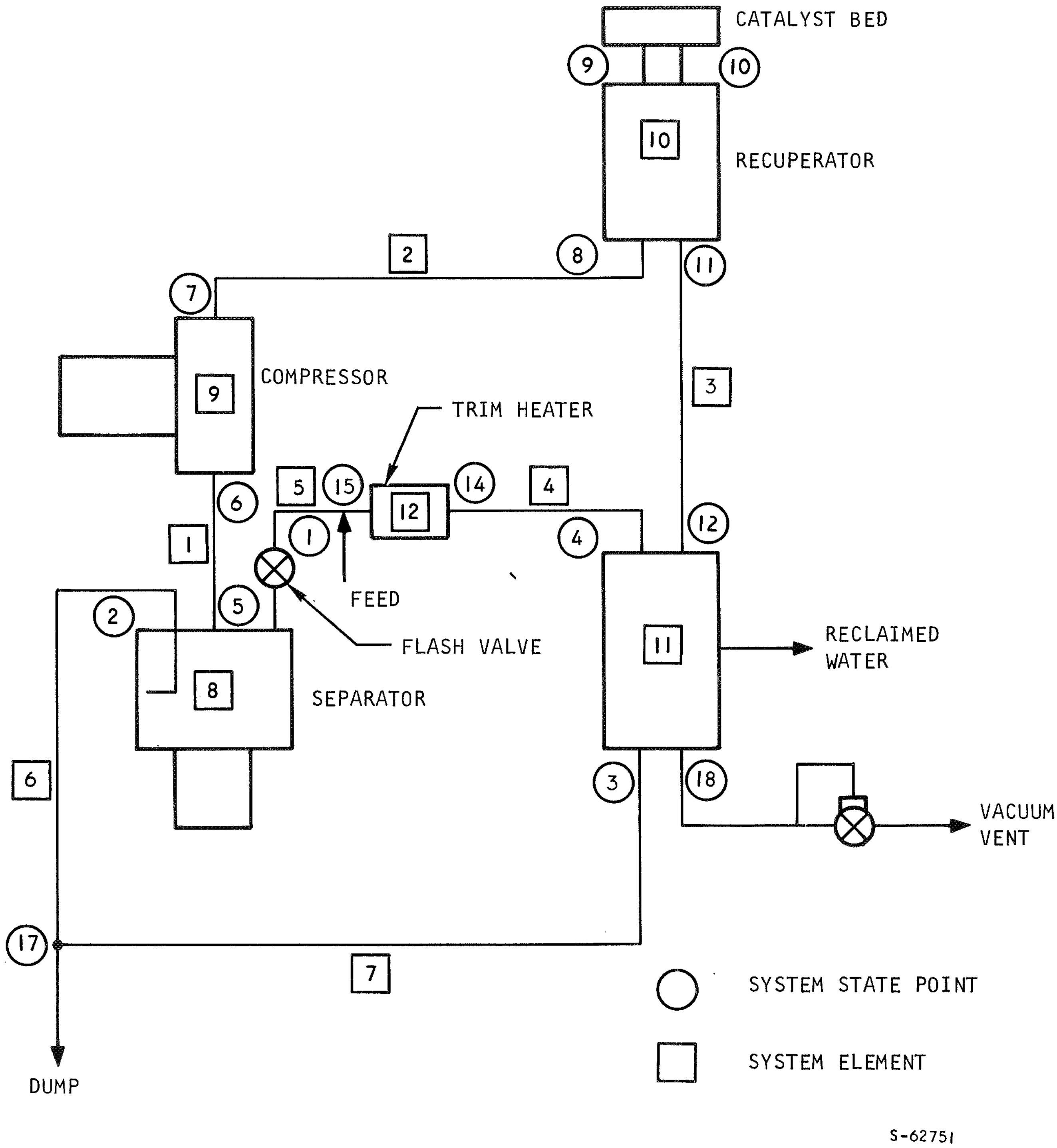


Figure B-1. Computer System Model

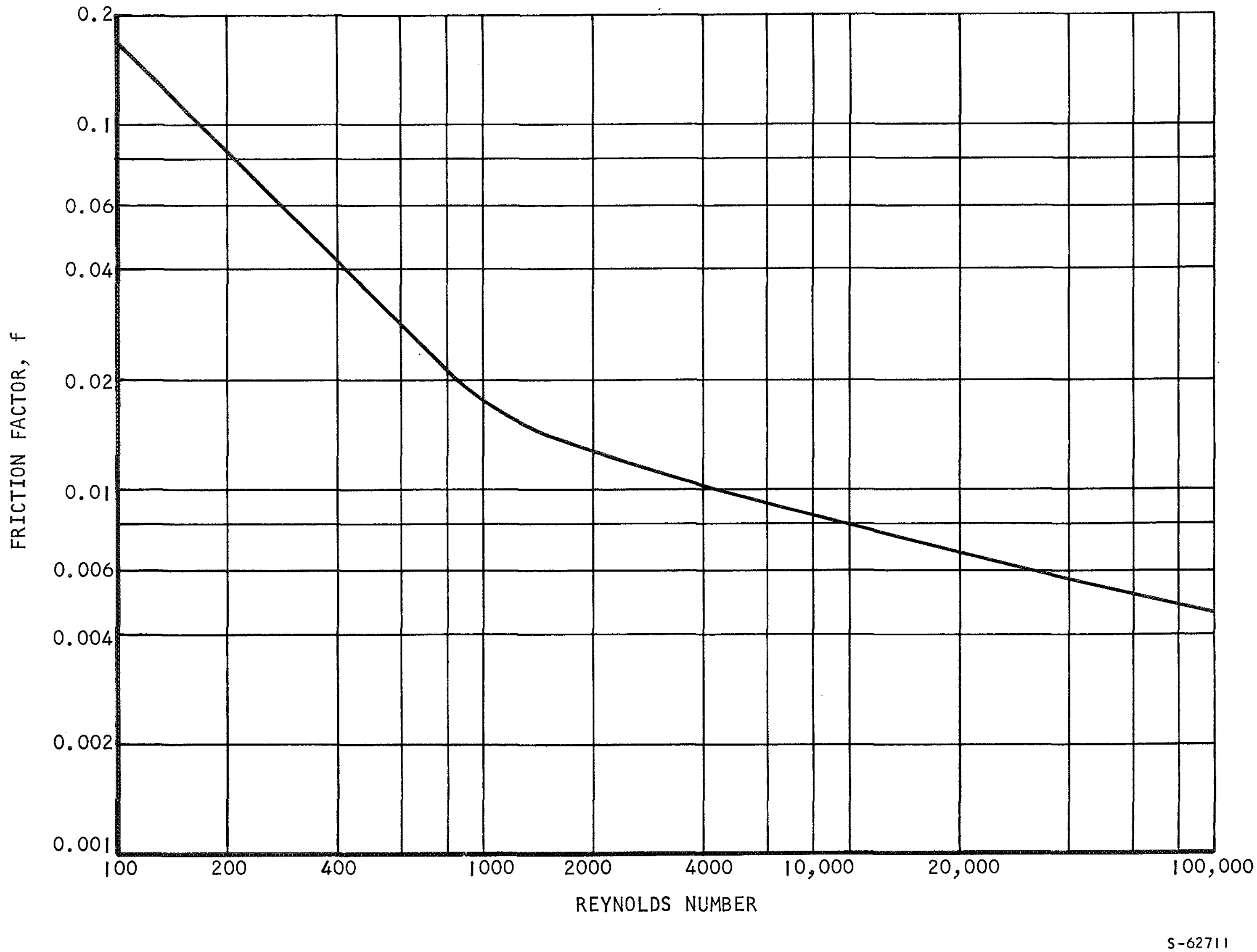


Figure B-2. Friction Factor for Tubes

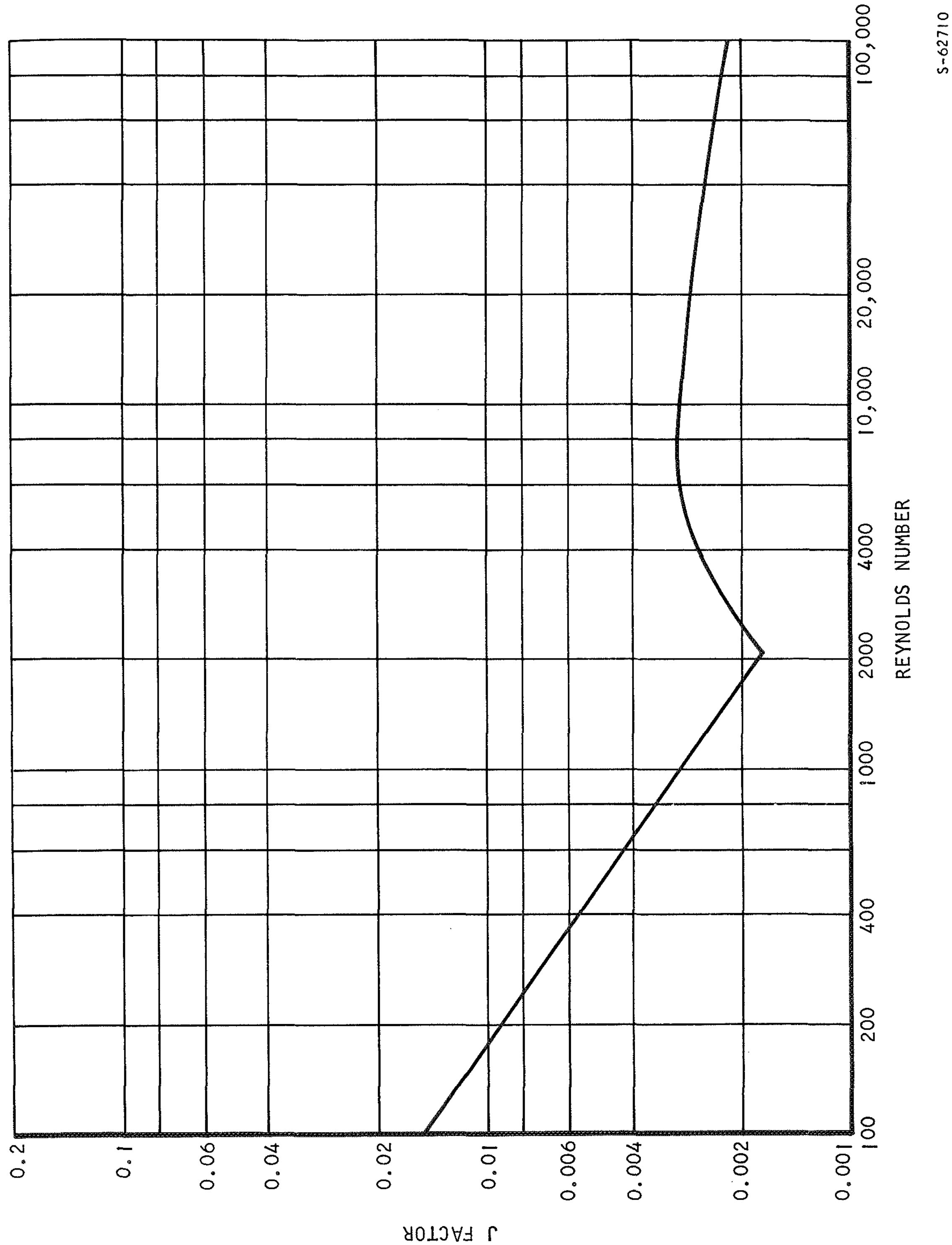


Figure B-3. J Factor vs Reynolds Number for Circular Tubes

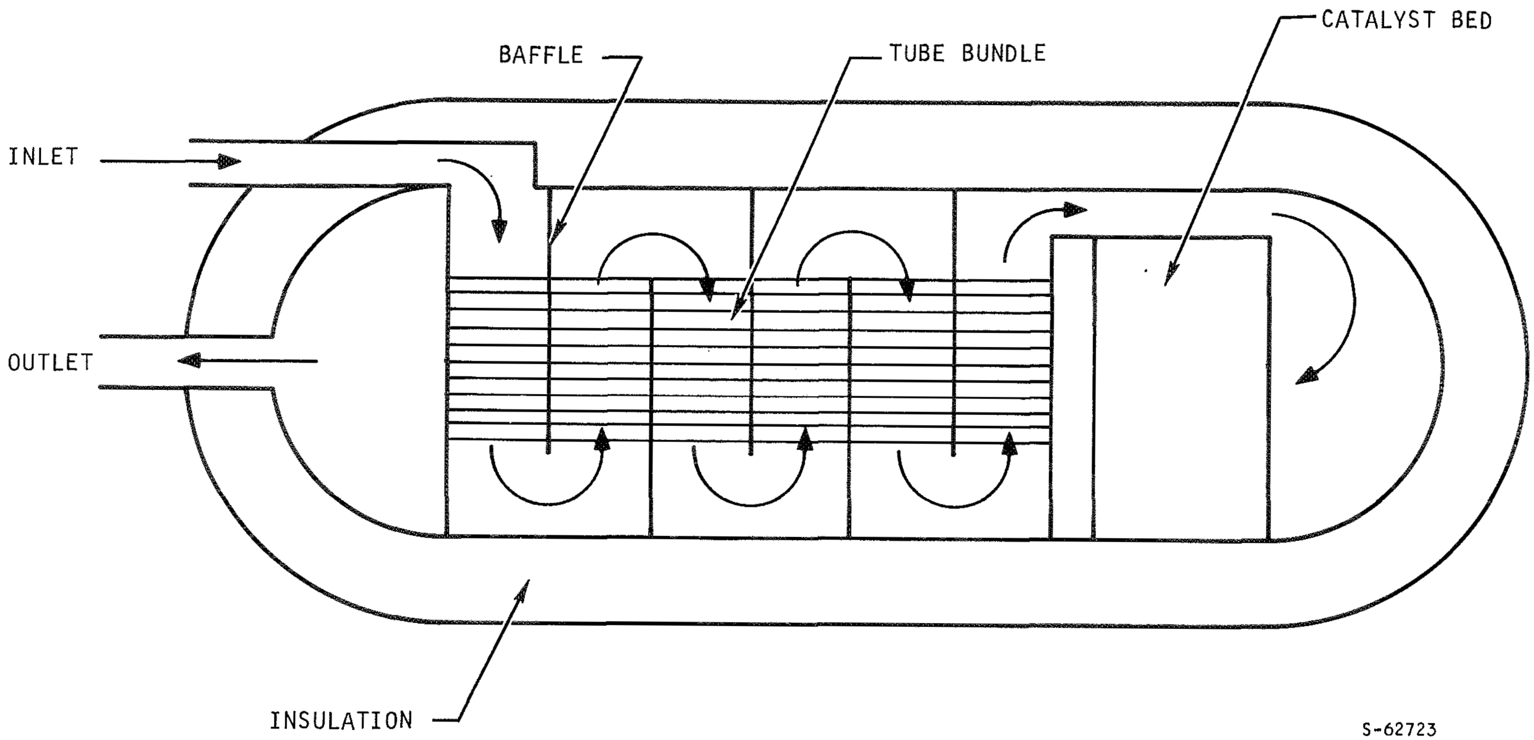


Figure B-4. Recuperator/Catalyst Bed Configuration

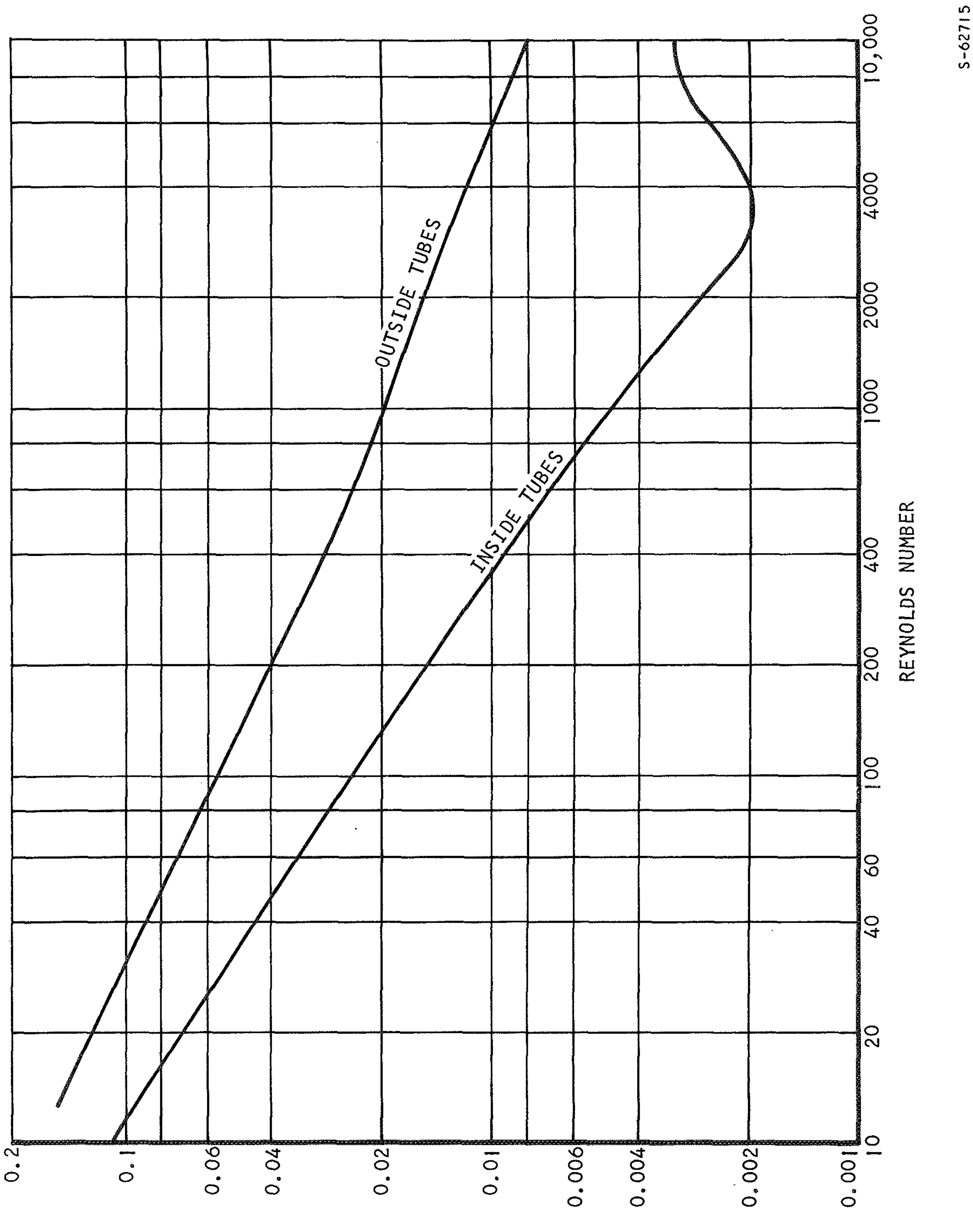


Figure B-5. J Factors for Flow in Recuperator

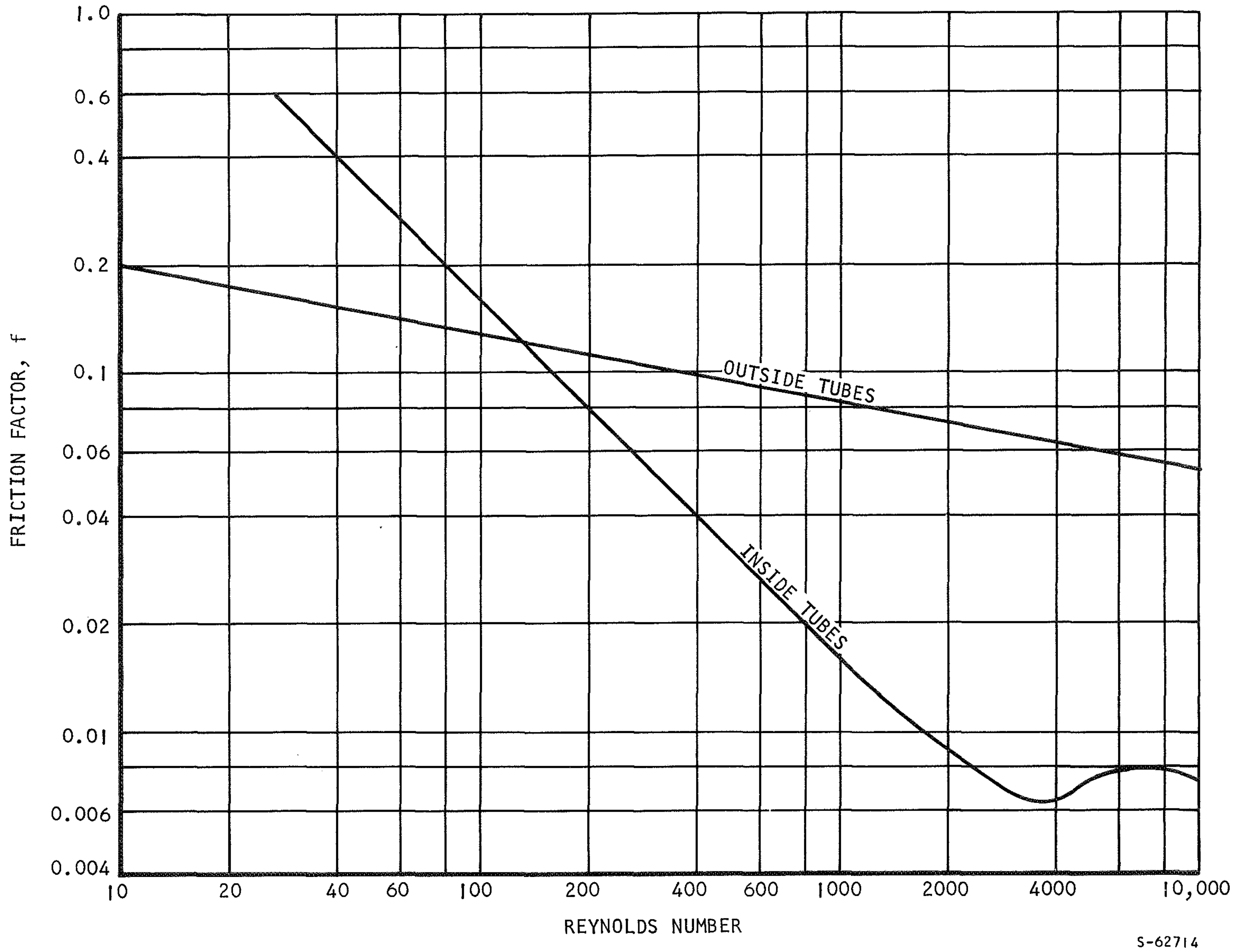


Figure B-6. Friction Factors for Flow in Recuperator

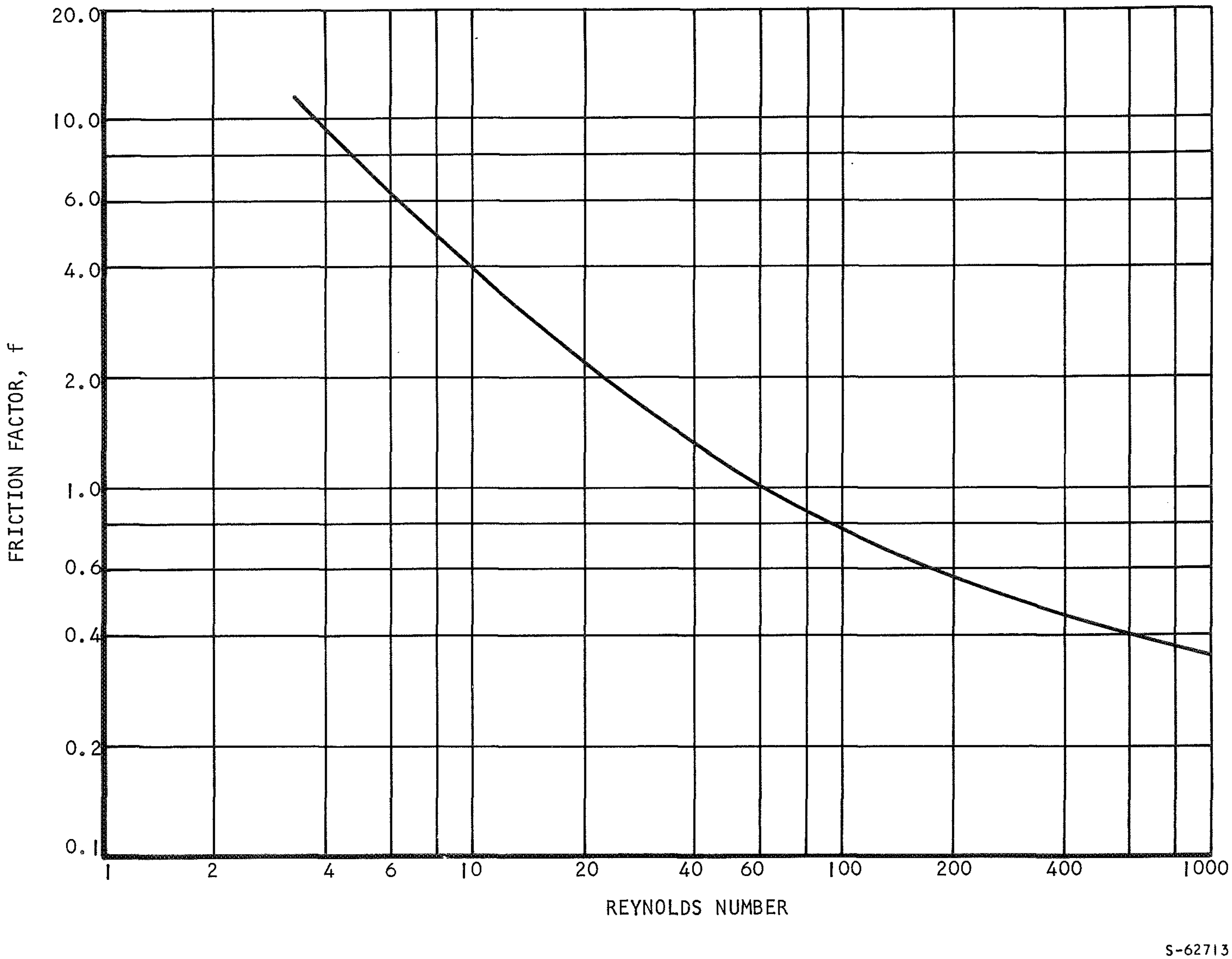


Figure B-7. Friction Factor for Flow Through Catalyst Bed

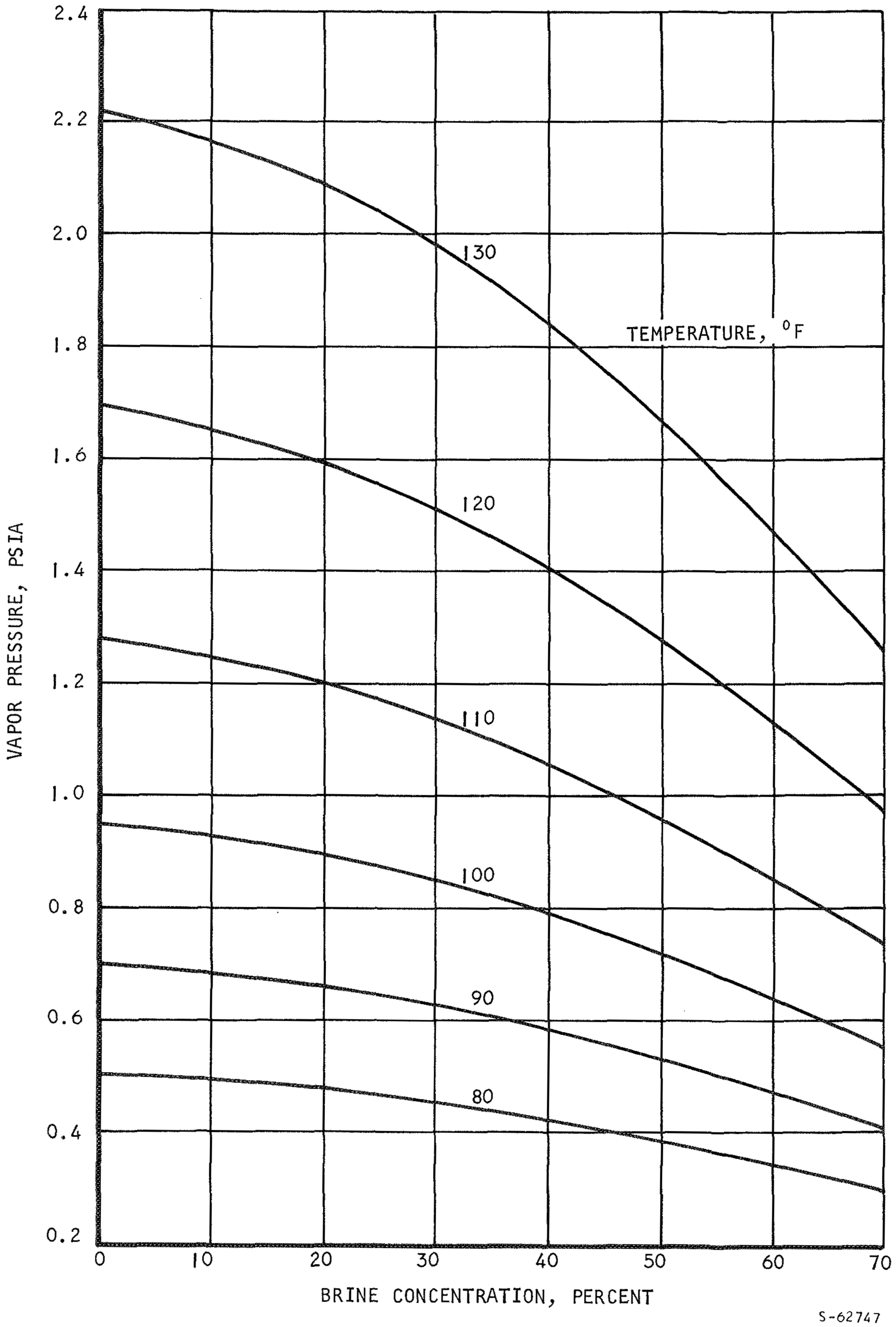


Figure B-8. Vapor Pressure of Brine

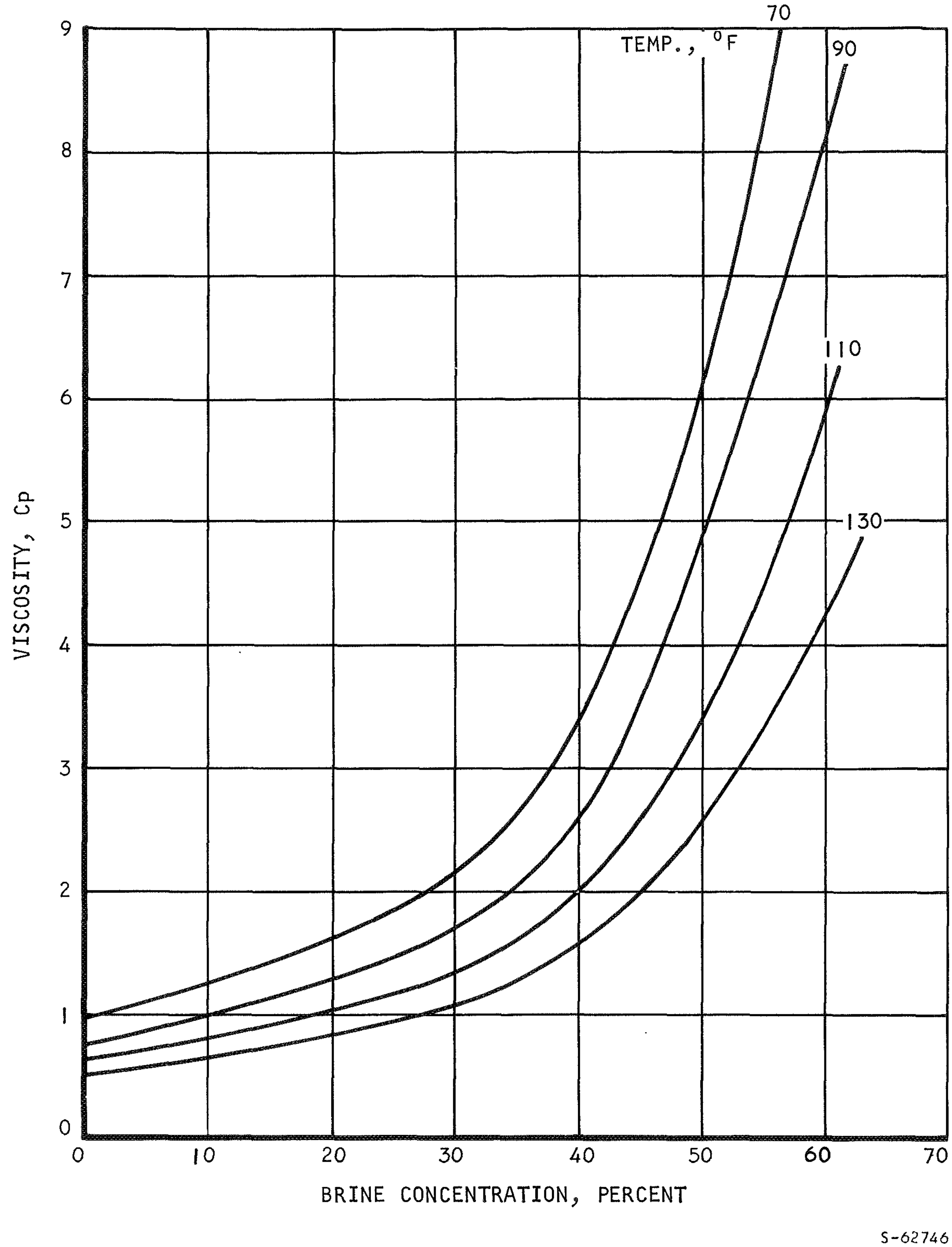


Figure B-9. Viscosity of Brine

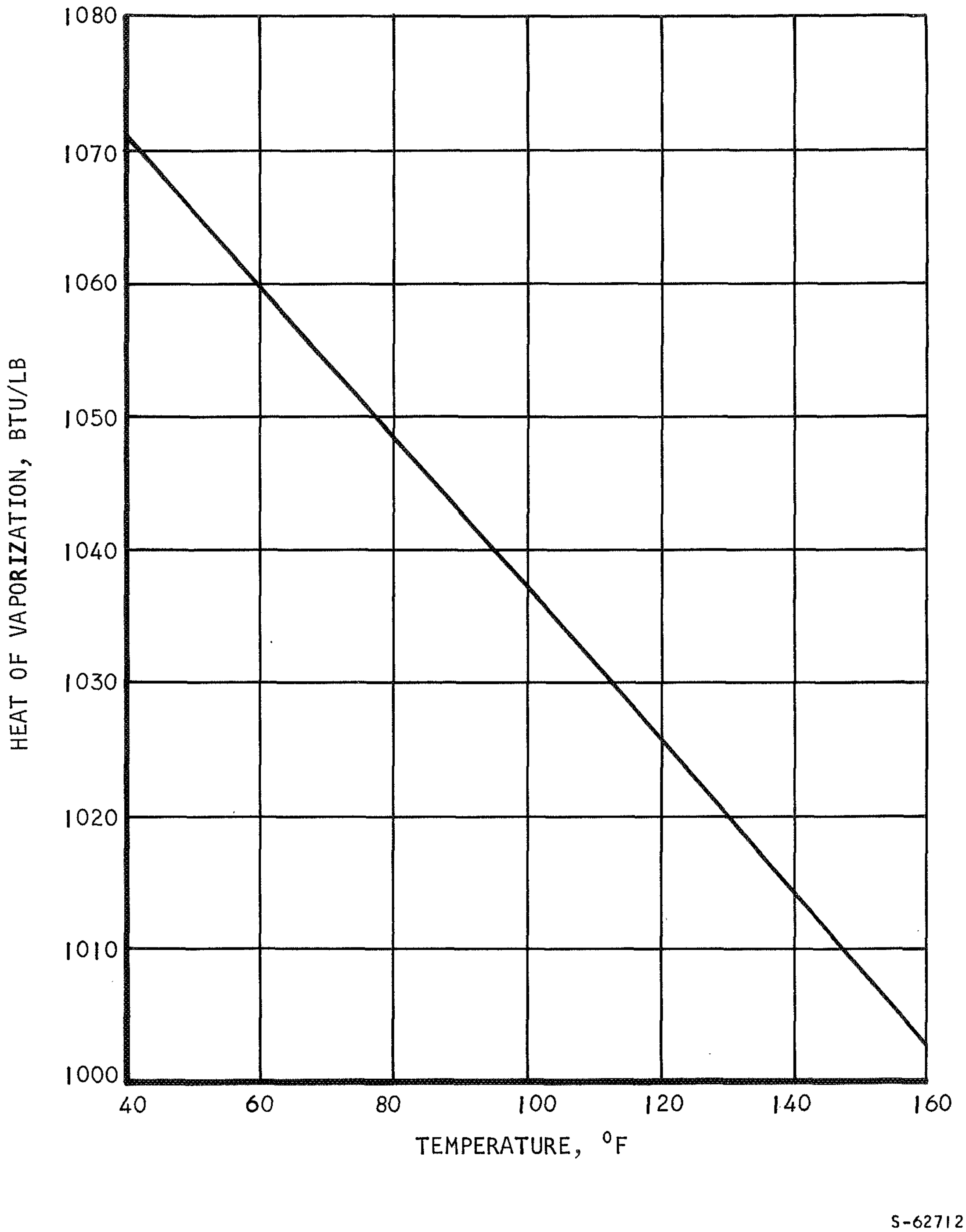


Figure B-10. Heat of Vaporization of Water

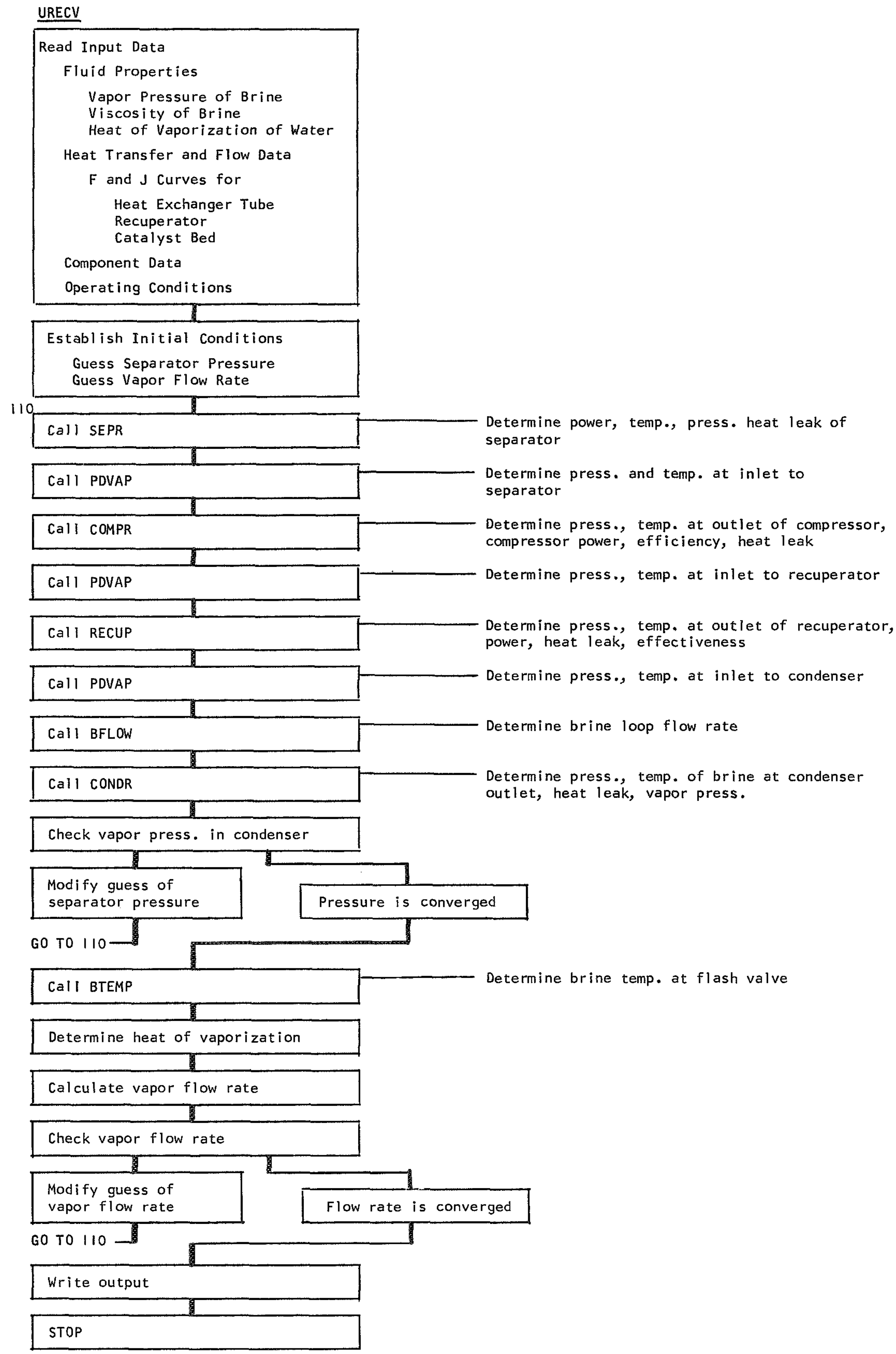


Figure B-11. Block Diagram of URECV

@ ELT URECV,1,701211, 38489 , 1

```
      C  MAIN PROGRAM FOR CALCULATION OF PERFORMANCE OF URINE RECOVERY SYSTEM
      C  PROGRAM USES THE FOLLOWING SUBROUTINES
      C
      C  UREAD --- READS FLUID PROPERTY DATA
      C  MAPROP--- LOOK UP ROUTINE FOR PRESSURE ,VISCOSITY VS. TEMP, CONCENTRATION
      C  BTEMP --- HEAT BALANCE OF BRINE LOOP
      C  BFLOW --- FLOW RATE OF   BRINE LOOP
      C  PDUAP --- PRESSURE DROP AND TEMP DROP OF SEGMENTS OF VAPOR LOOP
      C  SEPR  ---HEAD ,POWER, HEAT LEAK OF SEPARATOR
      C  COMPR --- PRESS,TEMP, POWER,HEAT LEAK OF COMPRESSOR
      C  RECUP --- TEMP,POWER,PRESS,HEAT LEAK OF CATALYST,RECUPERATOR
      C  COND  --- PERF. OF CONDENSER/BRINE HEATER
      C
            COMMON/GENRLD/ T(20),UA(20),P(20),QL(20),D(20),AL(20),REN(40),
           1NREN,JREN(40),RELL(40),NREL,FANFR(40),KPRINT,IPRINT
            COMMON/UPROP/TP(65),CP(20),PP(65,20),NTP,NCP,TH(43),HH(43),
           1NTH,CU(20),TV(65),VISB(65,20),NTV,NCV
            COMMON/COMPRD/VFLO(20),NPR  ,PRC(20),POWC(20),POW ,TB   ,PB,PE
            COMMON/CONDD/VPC(10),VTC(10),BTC(10),ALHX(10),DSEP(10),AFOUL,
           1TKSS,WVO
            COMMON/BFLOWD/WBRIN,CO,KDUMP,WDUMP
            COMMON/BTEMPD/KHEAT,QHEAT,CONF
            COMMON/SEPRD/OMEGA,DD,CD,DL,AK,PTR,SMV,POWS
            COMMON/RECUPD/ AC,AF,AB,TL,DT,ANT,ANP,AKC,ARXC,DBED,DW,ALBED,
           1AMESH,EFFH,DPC,DPT,DPB,RET(50),RETF(50),RETJ(50),NRET,
           2RES(50),RESF(50),RESJ(50),NRES,REB(50),REBEDF(50),NREB
            COMMON/PRINTX/TLHX
            DIMENSION HEAD(20),PCON(20),XB(20),ALEVEL(20),JPRINT(20),IFEED(20)
      C  READ REYNOLDS NUMBER VS F AND J FACTORS
      C  REN  = REYNOLDS NO. FOR  J CURVE
      C  JREN = J FACTOR FOR HEAT TRANSFER IN CIRCULAR TUBE - NO ENTRANCE CORRECTION
      C  RELL = REYNOLDS NO. FOR FRICTION FACTOR CURVE
      C  FANFR= FANNING FRICTION FACTOR
      C  GENERAL CONFIGURATION CONSTANTS OF THE SYSTEM
      C  UA   - CONDUCTANCE X AREA FOR CALCULATION OF COMPONENT HEAT LEAK TO AMBIENT
      C  AL   - LENGTH IN FEET OF INTERCONNECT N LINES
      C  D    - DIAMETER OF LINES (INSIDE)  - INCHES
      C  COMPONENT IDENTIFICATIONS
      C  LINES  -SUBSCRIPTS OF UA,AL,D,QL
      C  1 - SEPARATOR TO COMPRESSOR                  5 - FEED LINE TO SEPARATOR
      C  2 - COMPRESSOR TO RECUPERATOR                6 - SEPARATOR TO DUMP LINE
      C  3 - RECUPERATOR TO CONDENSER                 7 - DUMP LINE TO CONDENSER
      C  4 - CONDENSER TO FEED LINE
      C
      C  COMPONENTS - SUBSCRIPTS OF UA,AL,D,QL
      C  8 - SEPARATOR                                11  - CONDENSER
      C  9 - COMPRESSOR                               12  - TRIM HEATER
      C  NO- RECUPERATOR/REACTOR
      C
      C  COMPRESSOR PERFORMANCE DATA
      C  NVFLO  - NUMBER OF DATA POINTS IN FLOW,POWER,HEAD CURVES OF COMPRESSOR
      C  VFLO   - VOLUMETRIC FLOW AT INLET CONDITIONS - CFM
      C  PRC    - PRESSURE RATIO  OUTLET/INLET
      C  POWC   - POWER CONSUMED - WATTS
      C  TB     - TEMPERATURE AT WHICH VFLO,PRC AND POWC ARE DEFINED
      C  PB       PRESSURE AT WHICH VFLO, PRC, AND POWC ARE DEFINED
      C    PE     COMPRESSOR POWER AT ZERO INLET PRESSURE   WATTS
      C
      C  STATE POINTS IN SYSTEM PRESSURE,TEMPERATURE
      C  1 - INLET TO FLASH VALUE                    11 - RECUPERATOR OUTLET
      C  2 - OUTLET OF PITOT TUBE                    12 - CONDENSER STEAM INLET
      C  3 - BRINE INLET TO HX                       13 - CONDENSER WATER OUTLET
      C  4 - BRINE OUTLET FROM HX                     14 - BRINE TRIM HEATER INLET
      C  5 - SEPARATOR OUTLET -VAPOR                  15 - BRINE TRIM HEATER OUTLET
      C  6 - INLET TO COMPRESSOR                     16 -
      C  7 - OUTLET OF COMPRESSOR                    17 -
      C  8 - RECUPERATOR INLET                       18 - VACUUM VENT ON CONDENSER
```

Figure B-12. URECV Listing (Sheet 1 of 4)

```
C  9 - RECUPERATOR OUTLET TO CAT BURNER      19 - FEED TEMPERATURE
C  10 - RECUPERATOR INLET FROM CAT BURNER    20 - AMBIENT TEMPERATURE
C  CONDENSER DATA FOR SUBROUTINE CONDR
C  DSEP  = SPACING BETWEEN BRINE TUBES - IN
C  ALHX  = LENGTH OF BRINE TUBE
C  TKSS  = CONDUCTIVITY OF BRINE TUBE
C  AFOUL = BRINE SIDE FOULING FACTOR
C  OPERATING CONDITIONS FOR SYSTEM
C  PCOND = CONDENSER VENT PRESSURE-PSIA
C  XSTART= BRINE CONCENTRATION - PERCENT SOLIDS
C  ALMAX = SEPARATOR FLUID LEVEL (INCLUDING LINES) -CU.IN
C  CONF  = FEED  CONCENTRATION - PERCENT SOLIDS
C  TFEED = FEED  TEMPERATURE - DEG F
C  TAMB  = AMBIENT TEMPERATURE-DEG F
C  OMEGA = SEPARATOR SPEED -RPM
C  WFEED = FEED FLOW RATE -LB/HR
C  WDUMP = DUMP FLOW RATE -LB/HR
C  QHEAT = TRIM HEATER POWER -WATTS
      CALL UREAD
      READ (5,2) NREN ,NREL
      READ (5,1) (REN(I),JREN(I),I=1,NREN)
      READ (5,1) (RELL(I),FANFR(I),I=1,NREL)
      READ (5,2) M
      READ(5,1) (DSEP(I),ALHX(I),I=1,M)
      READ(5,1) TKSS,AFOUL
      READ(5,2)NRET
      READ(5,1) (RET(I),I=1,NRET)
      READ(5,1) (RETF(I),I=1,NRET)
      READ(5,1) (RETJ(I),I=1,NRET)
      READ(5,2) NRES
      READ(5,1) (RES(I),I=1,NRES)
      READ(5,1)(RESF(I),I=1,NRES)
      READ(5,1)(RESJ(I),I=1,NRES)
      READ(5,2) NREB
      READ(5,1) (REB(I),I=1,NREB)
      READ(5,1) (REBEDF(I),I=1,NREB)
   50 CONTINUE
      READ (5,1) AC,AF,TL,DT,ANT,ANP,AKC,ARXC,DBED,DW,ALBED,AMESH,EFFH,
     1DPC ,DPT,DPB,AB
      READ (5,3) NPR,PB,TB,PE
      READ(5,1)(VFLO(I),I=1,NPR)
      READ(5,1)(PRC(I),I=1,NPR)
      READ(5,1)(POWC(I),I=1,NPR)
      READ (5,1) (UA(I),I=1,12)
      READ (5,1) (AL(I),I=1,12)
      READ (5,1) (D(I), I=1,12)
      READ (5,4) HEAD
      READ(5,1) DD,DL,OMEGA
      READ(5,1) TAMB,TFEED,CONF,WDUMP,QHEAT,T(10)
      READ(5,2) NCASE
      READ(5,5)(PCON(I),XB(I),ALEVEL(I),JPRINT(I),IFEED(I),I=1,NCASE)
    5 FORMAT (3F10.0,2I10)
      T(20) = TAMB
      T(19) = TFEED
    1 FORMAT (8F10.0)
    2 FORMAT (8I10)
    3 FORMAT (I10,7F10.0)
    4 FORMAT (20A4)
C  INPUT STARTING CONDITIONS  KSTART = 1
C     IF (KSTART.EQ.0) GO TO 100
C  XXXX         STEADY STATE OPERATION                       XXX
  100 CONTINUE
      TLHX = 0.
      DO 120 I=1,M
  120 TLHX = TLHX+ALHX(I)
      DO 500 IJ=1,NCASE
      PCOND = PCON(IJ)
      CO    =  XB(IJ)
      ALEV  = ALEVEL(IJ)
```

Figure B-12. (Continued) (Sheet 2 of 4)

```
      IPRINT = JPRINT(IJ)
      KFEED = IFEED(IJ)
      WRITE (6,23)
   23 FORMAT(1H1)
      KS= 0
      KC= 0
      KPRINT=0
      T(19)=TFEED
      PRG  = 1.2 + 3.* CO
      ADIR = 1.
  102 PSEPG = PCOND/PRG
      WBRIN = 200.
      KCALP = 0
      KDUMP =0
      KHEAT =0
      WVG = 1.4 - 1.5*CO
      WVG = WVG*PCOND/1.5
      BDTC=WVG*5./(1.-.7*CO)
      DWVG=.12*WVG
      KWV1 = 0
      KWV2 = 0
      KP1=0
      KP2=0
      DPS  = .1 * PSEPG
      KCO = 0
      KCONV = 0
  105 WFEED = WVG
      DPS = .1*PSEPG
  110 CALL MAPRDP(001,CP,TP,PP,NCP,NTP,2,2,CO,TSEPG,PSEPG,2)
      CALL SEPR (001,ALEV,CO,TSEPG,PSEPG,KS)
      P(5) = PSEPG
      T(2) = TSEPG
      T(5) = TSEPG
  130 CONTINUE
      P(18)=PCOND
      WBRIN = 200.
  150 CONTINUE
      CALL PDVAP (001,1,5,6,WVG)
      CALL COMPR (001,WVG,KC)
      CALL PDVAP (002,2,7,8,WVG)
      CALL RECUP (WVG,PREC)
      CALL PDVAP (003,3,11,12,WVG)
      CALL BFLOW
      CALL CONDR (CO,WBRIN,WVG,QBRIN,PCOND)
C  XXX      CONVERGENCE ON CONDENSER PRESSURE     XXXX
      DPCOND=PCOND-P(18)
      IF(ABS(DPCOND/PCOND).LT..005) GO TO 200
      KCONV = KCONV + 1
      IF(KCONV.GT.30) GO TO 410
      IF(PCOND.LT.P(18)) GO TO 160
      KP1=1
      IF(KP1.EQ.1.AND.KP2.EQ.1) DPS = DPS*.5
      PSEPG = PSEPG +DPS
      GO TO 110
  160 KP2=1
      IF(KP1.EQ.1.AND.KP2.EQ.1) DPS = DPS*.5
      PSEPG = PSEPG -DPS
      GO TO 110
  200 CALL BTEMP(WBRIN,CO)
      CALL LAGIN2 (001,TH,NTH,2,T(1),H1,HH)
      CALL LAGIN2 (002,TH,NTH,2,TSEPG,H2,HH)
      HVAP =(H1 +H2)/2.
      CPBR = 1. - 0.7* CO
      CALL MAPRDP(002,CP,TP,PP,NCP,NTP,2,2,CO,TSEPG,P1 ,1)
      CALL MAPRDP(003,CP,TP,PP,NCP,NTP,2,2,CO,T(1) ,P2 ,1)
      CALL MAPRDP(004,CP,TP,PP,NCP,NTP,2,2,0.,TSEPG,P1X,1)
      CALL MAPRDP(005,CP,TP,PP,NCP,NTP,2,2,0.,T(1) ,P2X,1)
      HVAP = HVAP*ALOG(P1/P2)/ALOG(P1X/P2X)
      WVC=(POWS*3.41-QL(8) + WBRIN*CPBR*(T(1)-TSEPG))/HVAP
```

Figure B-12. (Continued) (Sheet 3 of 4)

```
      WRITE(6,22) WVC,WVG,HVAP,T(1),TSEPG,PSEPG,KCONV
   22 FORMAT(5X,6F10.4,I10)
C XXX       CONVERGENCE  ON VAPOR FLOW RATE      XXX
C
C
      DWV=WVC-WVG
      IF(ABS(DWV/WVG).LT..002) GO TO 400
      KCO = KCO + 1
      IF(KCO.EQ.1) DWV1 =DWV
      IF(KCO.NE.2) GO TO 205
      IF((DWV/DWV1).LT.0.) GO TO 205
      IF(ABS(DWV/DWV1).LT.1.) GO TO 205
      ADIR = -1.
      GO TO 102
  205 IF(WVC.LT.WVG) GO TO 220
      KWV1 =1
      IF (KWV1.EQ.1.AND.KWV2.EQ.1) DWVG = DWVG * .5
      WVG=WVG-ADIR*DWVG
      KCONV = 1
      GO TO 105
  220 KWV2=1
      IF(KWV1.EQ.1.AND.KWV2.EQ.1) DWVG =DWVG*.5
      WVG = WVG+ADIR*DWVG
      KCONV = 1
      GO TO 105
  400 IF (KPRINT.EQ.1) GO TO 500
      IF(KCO.GT.20) WRITE(6,21)
      GO TO 420
  410 IF(KCONV.GT.30) WRITE(6,20)
      GO TO 200
  420 KPRINT = 1
      CALL PRINTA (HEAD,IPRINT)
      PRW=P(7)/P(6)
      CALL PRINTB (ALEV,CO,CONF,B4,IPRINT,PCOND,B6)
      CALL PRINTC (WVG,PRW,WBRIN,POWS,POW,PREC,IPRINT,C7,C8)
      IF (IPRINT.EQ.2) CALL PRINTD (IPRINT)
      CALL SEPR (002,ALEV,CO,TSEPG,PSEPG,KS)
      CALL COMPR (002,WVG,KC)
      CALL RECUP (WVG,PREC)
      CALL CONDR (CO,WBRIN,WVG,QBRIN,PCOND)
   20 FORMAT (10X,'CONDENSER PRESSURE NOT CONVERGED IN UREVC')
   21 FORMAT(10X,'FLOW RATE NOT CONVERGED IN URECV')
  500 CONTINUE
      GO TO 50
      STOP
      END
```

Figure B-12. (Continued) (Sheet 4 of 4)

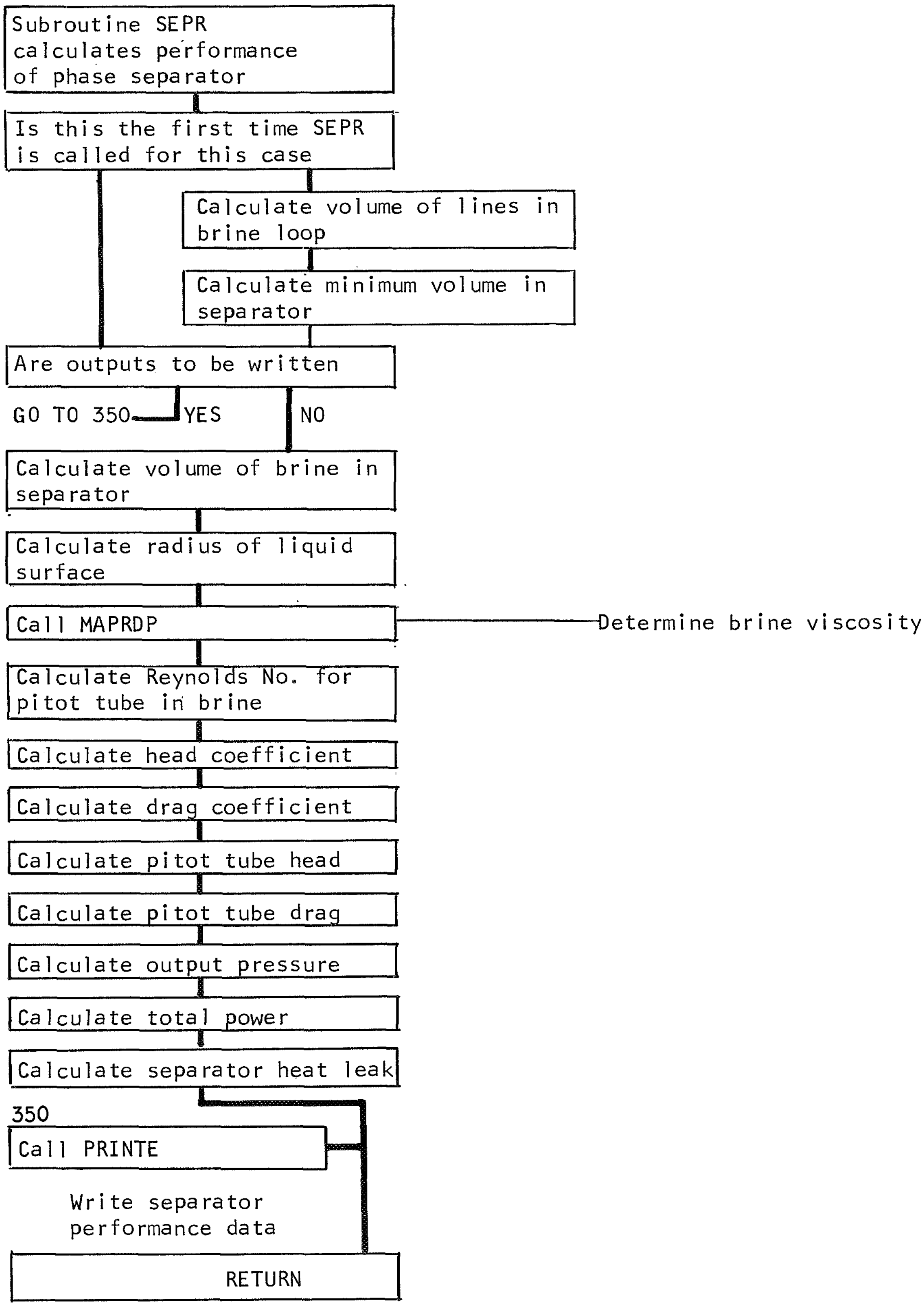


Figure B-13. Block Diagram of SEPR

```
@ FLT SEPR,1,701208, 55608     , 1
      SUBROUTINE SEPR(ID,SL,CX,TS,PS,K)
C  SUBROUTINE TO CALCULATE THE SEPARATOR HEAD,POWER,AND HEAT LEAK     CODE NO 5
      COMMON/GENRLD/ T(20),UA(20),P(20),QL(20),D(20),AL(20),REN(40),
     1NREN,JREN(40),RELL(40),NREL,FANFR(40),KPRINT,IPRINT
      COMMON/UPROP/TP(65),CP(20),PP(65,20),NTP,NCP,TH(43),HH(43),
     1NTH,CU(20),TV(65),VISB(65,20),NTV,NCV
      COMMON/SEPRD/OMEGA,DD,CD,DL,AK,PTR,SMV,POWS
   10 IF(K.EQ.1) GO TO 50
      RG = 2.
      VL =   (D(9)*D(9)*AL(9)+D(6)*D(6)*AL(6) +D(7)*D(7)*AL(7)+D(10)*D(10
     1)*AL(10) + D(4)*D(4)*AL(4)+D(8)*D(8)*AL(8)+D(5)*D(5)*AL(5))
     2*3.1416 *12. /4.
      RD=DD/2.
      L2= DL-2.
      RB = RD-1.
      PTR=RD-.3                                                         *NEW
      RR = RB + .25                                                     **-1
      A1 = 3.1416/8.
      V1 = 2.*3.1416*RR*A1
      V4 = 3.1416*L2*(RD*RD-RB*RB)
      VR = 3.1416*DD*.03
      SMV = 2.*3.1416*RD*.25*(DL-1.)
      K  = 1
C
   50 IF(KPRINT.EQ.1) GO TO 350
      K1=0
      K2 = 0
      DR = .1
      V2 = SL-VL-VR
      IF (V2.LT.0.) GO TO 1000
   70 V3 = 3.1416*DL*(RB*RB-RG*RG)
      IF(RG.LT.RB) GO TO 80
      R31R = RB+2.*(RG-RB)/3.
      A31 = (RG-RB)*(RG-RB)*7./27.
      V31 = V3+V31
   80 VG = V1+V4+V3
      DV = V2 - VG
      IF (ABS(DV/V2).LT..001) GO TO 200
      IF (DV.LT.0.) GO TO 100
      K1 = 1
      IF (K1.EQ.1.AND.K2.EQ.1) DR=.5*DR
      RG = RG -DR
      GO TO 70
  100 K2 = 1
      IF(K1.EQ.1.AND.K2.EQ.1) DR=.5*DR
      RG = RG +DR
      GO TO 70
  200 CALL MAPROP(501,CU,TV,VISB,NCV,NTV,2,2,CX,TS,VIS,1)
      RAVG = (RD+RG)/2.
      VAVG = 2.* 3.1416 *RAVG * OMEGA/720.
      RHOB = (.4775 *CX +.99325)* 62.43
      RENB=.25*VAVG*RHOB/12./VIS/.000672
      CD=.756/(RENB**.16)
      AK=.728/(RENB**.15)
      PH=(1.-AK)**2*RHOB*PTR**2*(2.*3.1416*OMEGA/60.)**2/64.32          *NEW
     1/(12.**4)                                                         **-1
      POWS = CD*.25*RHOB*(2.*3.1416*OMEGA/60.)**3*(RD**4-RG**4)/8./
     132.16/778./(12.**5) *3600.
      GO TO 300
 1000 POWS = 0.
      PH   = 0.
  300 PE  = .0075*OMEGA
      POWS = PE +POWS/3.41
      P(2) = PH + PS
      QL(8) =(TS -T(20))*UA(8)
      GO TO 400
  350 IF(IPRINT.NE.2) GO TO 400
      CALL PRINTE(OMEGA,P(2),POWS,T(2),P(5),QL(8),E7,E8,IPRINT)
  400 RETURN
      END
```

Figure B-14. SEPR Listing

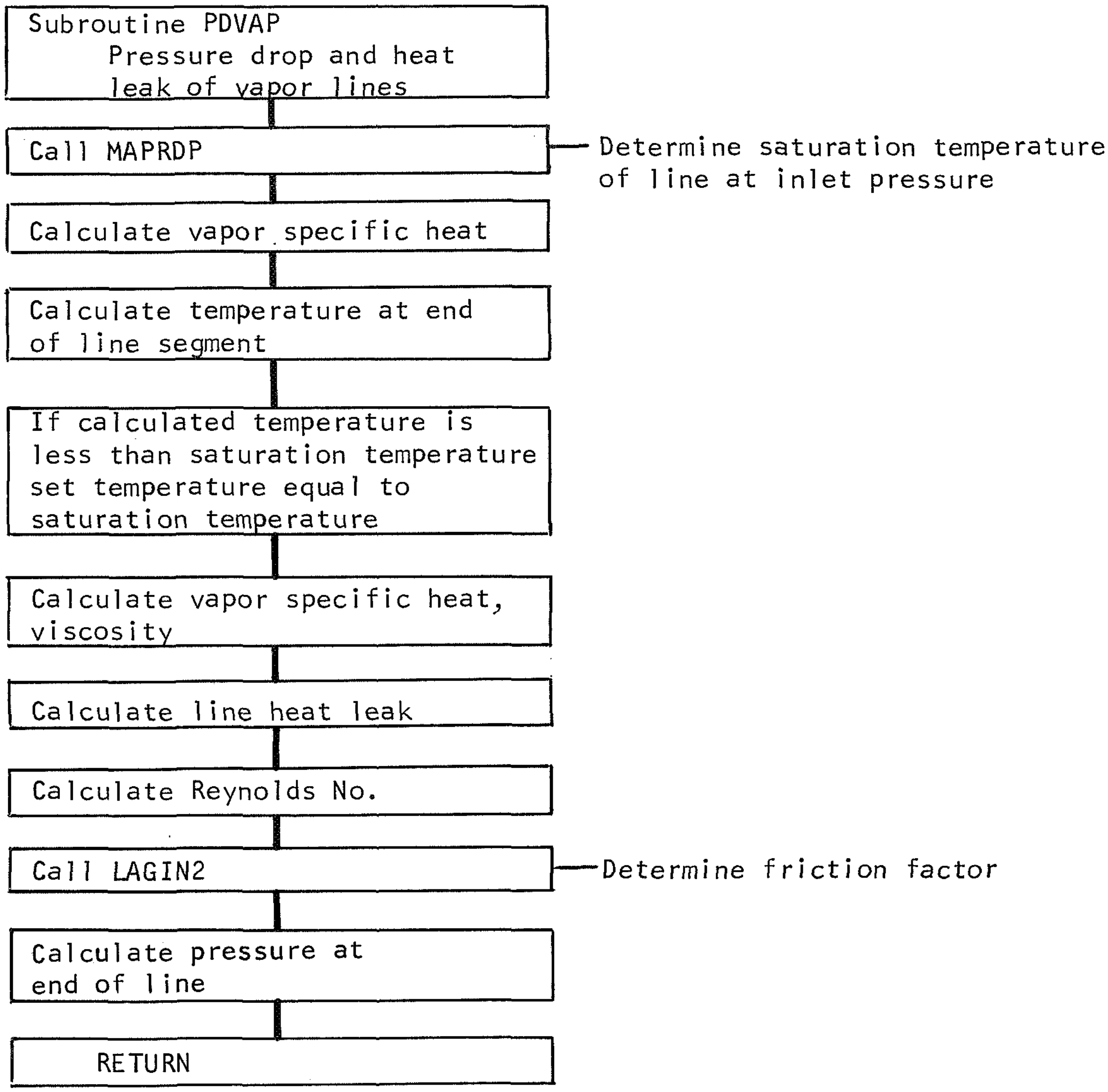


Figure B-15. Block Diagram of PDVAP

```
@ ELT PDVAP,1,701214, 60872    , 1

      SUBROUTINE PDVAP (ID,I,J,K,WV)
C     CALCULATES  PRESSURE DROP  OF VAPOR LINES
C  I  =    INCREMENT NUMBER    J= START OF INCR. NO. K=END OF INCR NO.
C  WV = VAPOR FLOW RATE
      COMMON/GENRLD/ T(20),UA(20),P(20),QL(20),D(20),AL(20),REN(40),
     1NREN,JREN(40),RELL(40),NREL,FANFR(40),KPRINT,IPRINT
      COMMON/UPROP/TP(65),CP(20),PP(65,20),NTP,NCP,TH(43),HH(43),
     1NTH,CU(20),TV(65),VISB(65,20),NTV,NCV
      IF(KPRINT.EQ.1) GO TO 100
      DDT = 10.
      K1 = 0
      K2 = 0
      LOOP = 0
      CALL MAPRDP (401,CP,TP,PP,NCP,NTP,0,0,0.,TSAT,P(J),2)
      TC = TSAT
   10 TBAR = (TC+T(J))/2.
      CPV = .46 + .048*(TBAR-300.)/700.
      T(K) = T(J) - UA(I)*(TBAR-T(20))/WV/CPV
      DT = TC-T(K)
      IF(ABS(DT/(TC+T(K))).LE..01) GO TO 70
      LOOP = LOOP + 1
      IF(LOOP.GE.20) GO TO 70
      IF(DT.LE.0.) GO TO 40
      IF(K1.EQ.1.AND.K2.EQ.1) DDT = DDT*.5
      K1 = 1
      TC = TC-DDT
      GO TO 10
   40 IF(K1.EQ.1.AND.K2.EQ.1) DDT = DDT*.5
      K2 = 1
      TC = TC +DDT
      GO TO 10
   70 IF(T(K).LE.TSAT) T(K) = TSAT
      TBAR = (T(K) + T(J))/2.
      CPV = .46 + .048*(TBAR-300.)/700.
      QL(I) = UA(I)*(TBAR-T(20))
      UVAP =1.81 + .0089*(TBAR**.88)*.032174*.36
      RE = 4.*WV/3.14159/UVAP/D(I)
      CALL LAGIN2 (401,RELL,NREL,2,RE,FA,FANFR)
      A1  = P(J)* P(J)
      B1 = 4.*12./3600./3600./32.16*FA*WV*WV*85.8*(TBAR+460.)*AL(I)/3.14
     116/3.1416/(D(I)**5)
      IF(B1.GT.A1) GO TO 50
      P(K) = (A1 - B1)**.5
      GO TO 100
   50 WRITE(6,1) I,J,K,AL(I),D(I)
  100 RETURN
    1 FORMAT(10X,'ERROR IN PDVAP I =',I6,3X,'J =',I6,3X,'K =',I6,3X,'AL(
     1I) =',F10.4,3X,'D(I) =',F10.4)
      END

END CUR
```

Figure B-16. PDVAP Listing

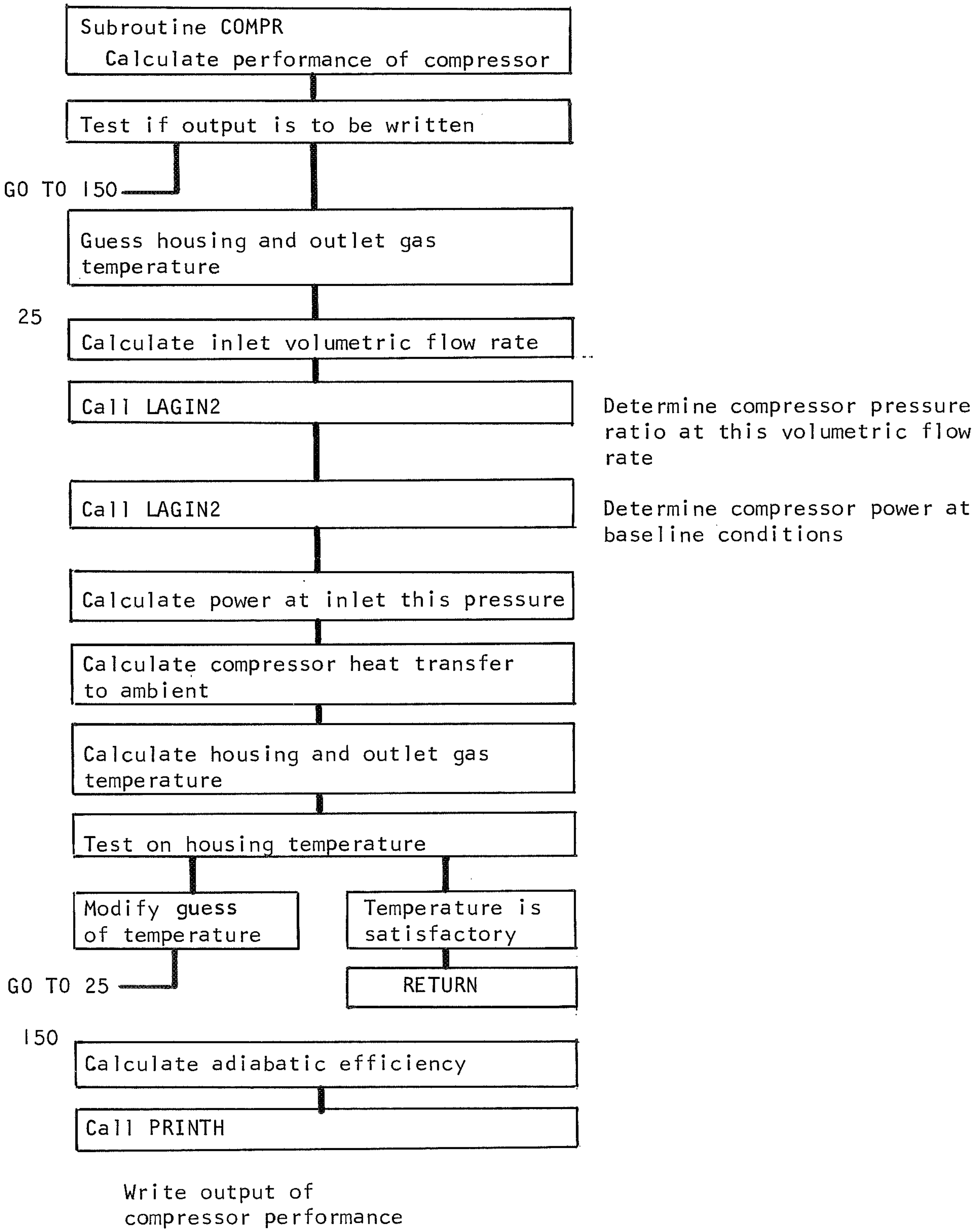


Figure B-17. Block Diagram of COMPR

```
@ ELT COMPR,1,701211, 38494    , 1
      SUBROUTINE COMPR(ID,WV,KC)
C  CALCULATES THE HEAD,TEMP,AND POWER OF THE COMPRESSOR  PROGRAM CODE NO 6
      COMMON/GENRLD/ T(20),UA(20),P(20),QL(20),D(20),AL(20),REN(40),
     1NREN,JREN(40),RELL(40),NREL,FANFR(40),KPRINT,IPRINT
      COMMON/COMPRD/VFLO(20),NVFLO,PRC(20),POWC(20),POW,TB,PB,PE
      IF(KPRINT.EQ.1) GO TO 150
      K1 = 0
      K2 = 0
      RGAS = 85.8
      GAMMA=1.322
      AG= (GAMMA-1.)/GAMMA
      KLOOP = 0
   10 IF(KC.EQ.1) GO TO 20
      TG  = 660.
      KC = 1
   20 DDT = 10.
   25 RHOG = P(6)*144./RGAS/TG
      TA = TG -460.
      QVAP = WV/60./RHOG
      CALL LAGIN2(601,VFLO,NVFLO,2,QVAP,PR,PRC)
      CALL LAGIN2 (602,VFLO,NVFLO,2,QVAP,POW,POWC)
      IF(POW.LT.0.) POW=0.
      IF(PR.LT.1.) PR=1.
      PRA = PR
      POW = POW*P(6)/PB*TB/TG + PE
      TBAR = (T(6) + TA)/2.
      CPV = .46 + .048*(TBAR-300.)/700.
      QL(9) = (TA-T(20))*UA(9)
      T(7) = T(6) + (POW*3.41-QL(9))/WV/CPV
      DT = T(7) - TA
      IF(ABS(DT/T(7)).LT..0005) GO TO 100
      KLOOP = KLOOP + 1
      IF(KLOOP.EQ.20) GO TO 900
      IF(DT.LT.0.) GO TO 50
      K1 = 1
      IF (K1.EQ.1.AND.K2.EQ.1) DDT= DDT*.5
      TG = TG +DDT
      GO TO 25
   50 K2 = 1
      IF (K1.EQ.1.AND.K2.EQ.1) DDT= DDT*.5
      TG = TG - DDT
      GO TO 25
  100 P(7) = P(6)*PRA
      GO TO 1000
  150 IF(IPRINT.NE.2) GO TO 1000
      GPOW = P(6)*QVAP*((P(7)/P(6))**AG-1.)/AG
      AEFF = GPOW*100.*3.26/POW
      CALL PRINTF(P(6),POW,P(7),AEFF,PR,T(7),QVAP,QL(9),IPRINT)
      GO TO 1000
  900 WRITE(6,1) T(7),TA
    1 FORMAT(10X,'TEMP NOT CONVERGED IN COMPR'/10X,'T(7) =',F10.4,'TA ='
     1,F10.4)
      GO TO 100
 1000 RETURN
      END
```

Figure B-18. COMPR Listing

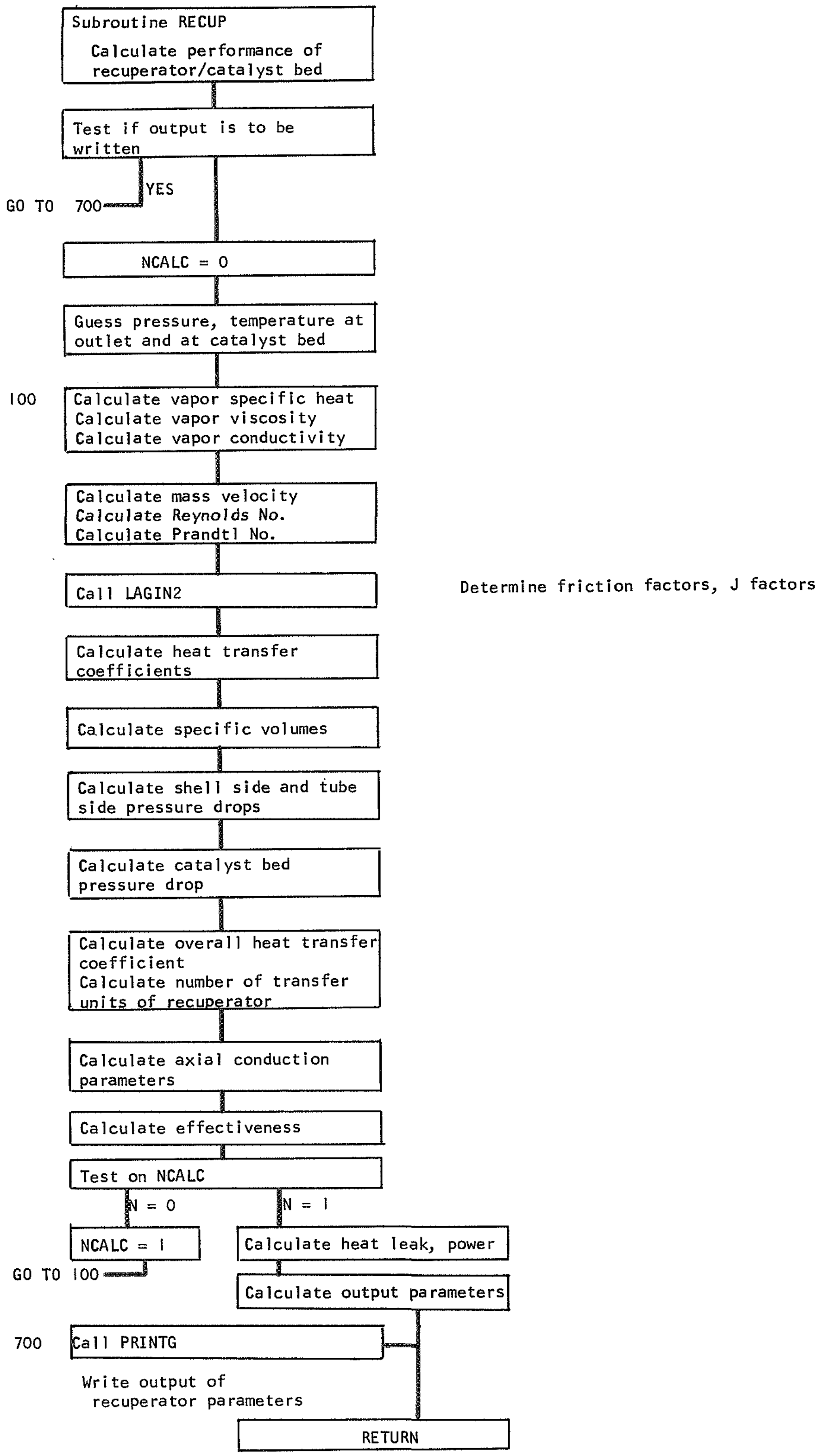


Figure B-19. Block Diagram of RECUP

@ ELT RECUP,1,701211, 38499   , 1

```
            SUBROUTINE RECUP (WV,PREC)
      C  SUBROUTINE RECUP  TO CALC HT. TRANSFER CHARACTERISTICS OF RECUPERATOR/
      C  CATALYST BED
      C  INPUTS TO SUBROUTINE ARE INLET PRESSURE,TEMPERATURE AND VAPOR FLOW RATE
      C  OUTPUTS ARE OUTLET CONDITIONS (P,T),POWER AND HEAT LEAK
      C  REQUIRED  DATA
      C     AC  -  MINIMUM FREE FLOW AREA ON SHELL SIDE/PASS                - FT**2
      C     AF  -  FRONTAL AREA ON SHELL SIDE /PASS                         - FT**2
      C     AB  -  FREE FLOW AREA ACROSS BAFFLE                             - FT**2
      C     AL  -  TUBE BUNDLE LENGTH                                       - FT
      C     DT  -  TUBE DIAMETER  (INSIDE)                                  - IN
      C     ANT -  NUMBER OF TUBES
      C     ANP -  NUMBER OF PASSES ON SHELL SIDE
      C     AKC -  THERMAL CONDUCTIVITY OF TUBE/SHELL MATERIAL        BTU/HR-FT-DEGF
      C     ARXC-  HEAT TRANSFER AREA FOR AXIAL CONDUCTION                  - FT**2
      C     DBED-  CATALYST BED DIAMETER                                    - IN
      C     DW  -  SCREEN WIRE  DIAMETER                                    - IN
      C     ALBED- CATALYST BED LENGTH                                      - IN
      C     AMESH- SCREEN WIRE MESH                                         - 1/IN
      C     EFFH-  INITIAL GUESS ON HX EFFECTIVENESS
      C     DPC -  INITIAL GUESS ON PRESSURE DROP IN CATALYST BED           - PSID
      C     DPT -  INITIAL GUESS ON PRESSURE DROP OF TUBE SIDE              - PSID
      C     DPB -  INITIAL GUESS ON PRESSURE DROP OF SHELL SIDE             - PSID
            COMMON/RECUPD/ AC,AF,AB,TL,DT,ANT,ANP,AKC,ARXC,DBED,DW,ALBED,
           1AMESH,EFFH,DPC,DPT,DPB,RET(50),RETF(50),RETJ(50),NRET,
           2RES(50),RESF(50),RESJ(50),NRES,REB(50),REBEDF(50),NREB
            COMMON/GENRLD/ T(20),UA(20),P(20),QL(20),D(20),AL(20),REN(40),
           1NREN,JREN(40),RELL(40),NREL,FANFR(40),KPRINT,IPRINT
            ATUBE =3.1416 *DT /12. *ANT * TL
            AOUT   =ATUBE * (DT +.005)/DT
            AAVG  = (AOUT + ATUBE)/2.
            IF(KPRINT.EQ.1) GO TO 700
            A  = AOUT /ANP
            NCALC = 0
            RG  = 85.8
            CC1 = 3600.*32.2
            SIGMA = AC/AF
            ANB  = ANP -1.
      C
      C  ESTABLISH INITIAL GUESS ON CONDITIONS
        100 T9G  = EFFH* (T(10) -T(8)) +T(8)
            T11G = EFFH* (T(8) - T(10))+T(10)
            P9G  = P(8)-DPB
            P10G = P9G -DPC
            P11G = P10G-DPT
            IF(NCALC.EQ.2) GO TO 500
      C
      C  LOOKUP AND CALCULATE FLUID PROPERTIES
      C  SPECIFIC HEAT OF VAPOR                         -  BTU/LB-DEG F
      C
            CP8 = .46 +.048 *(T(8)-300.)/700.
            CP9  = .46 +.048 *(T9G -300.)/700.
            CP10 = .46 + .048 *(T(10)-300.)/700.
            CP11 = .46 +.048 *(T11G-300.)/700.
      C  VISCOSITY OF VAPOR                             -  LBM/FT-HR
            AMU8 = (1.81+.0089*T(8)**.88)*10.**(-7) *CC1
            AMU9 = (1.81+.0089*T9G**.88)*10.**(-7)*CC1
            AMU10= (1.81+.0089*T(10)**.88)*10.**(-7)*CC1
            AMU11= (1.81+.0089*T11G *.88)*10.**(-7)*CC1
      C
      C  CONDUCTIVITY OF VAPOR                          -  BTU/HR-FT-F
            AK8  = (9.2 +25.5*(T(8)-32.)/968.)*10.**(-3)
            AK9  = (9.2 +25.5*(T9G -32.)/968.) *10.**(-3)
            AK10 = (9.2 +25.5*(T(10)-32.)/968.)*10.**(-3)
            AK11 = (9.2 +25.5*(T11G -32.)/968.)*10.**(-3)
      C
      C  MASS VELOCITIES                                -  LBM/HR-FT-FT
            G8   = WV/AC
            G9   = G8
            G10  = WV/ANT/3.1416/DT/DT*4.*144.
```

Figure B-20. RECUP Listing (Sheet 1 of 3)

```
      G11  = G10
C
C  REYNOLDS NUMBER
      ANR8 = 4.*AC*TL/A *G8/AMU8
      ANR9 = 4.*AC*TL/A *G9/AMU9
      ANR10= DT/12.*G10 /AMU10
      ANR11= DT/12.*G11 /AMU11
C
C  PRANDTL NUMBERS
      PR8 = AMU8 *CP8 /AK8
      PR9 = AMU9 *CP9 /AK9
      PR10= AMU10*CP10/AK10
      PR11= AMU11*CP11/AK11
C
C  FRICTION FACTORS
      CALL LAGIN2 (801,RET,NRET,2,ANR8,AF8,RETF)
      CALL LAGIN2 (802,RET,NRET,2,ANR9,AF9,RETF)
      CALL LAGIN2 (803,RES,NRES,2,ANR10,AF10,RESF)
      CALL LAGIN2 (804,RES,NRES,2,ANR11,AF11,RESF)
C
C  J  FACTORS
      CALL LAGIN2 (805,RET,NRET,2,ANR8,AJ8,RETJ)
      CALL LAGIN2 (806,RET,NRET,2,NAR9,AJ9,RETJ)
      CALL LAGIN2 (807,RES,NRES,2,ANR10,AJ10,RESJ)
      CALL LAGIN2 (808,RES,NRES,2,ANR11,AJ11,RESJ)
C
C  HEAT TRANSFER COEFFICIENTS                     -  BTU/HR-FT-FT-F
      AH8   =   AJ8 *G8 * CP8 / (PR8**.667)
      AH9   =   AJ9 *G9 * CP9 / (PR9**.667)
      AH10  =   AJ10*G10*CP10/(PR10**.667)
      AH11  =   AJ11*G11* CP11/(PR11**.667)
C
C  SPECIFIC VOLUMES AND MEAN TEMPERATURES     -  FT-FT-FT/LBM     F
      T89M = (T(8) +T9G)/2.
      P89M = P(8) -DPB/2.
      V8 = RG*(T(8)  +460.)/P(8) /144.
      V9 = RG*(T9G  +460.)/P9G/144.
      V89M = RG*(T89M + 460.)/P89M/144.
      V10 = RG*(T(10) +460.)/P10G/144.
      V11 = RG*(T11G +460.)/P11G/144.
      T1011M=(T(10)+T11G)/2.
      P1011M= P10G-DPT/2.
      V1011M = RG*(T1011M +460.)/P1011M/144.
C
C  SHELL PRESSURE DROP                            - PSIA
      GB    = WV /AB
      AF89 = (AF8+AF9)/2.
      DPB1 = G8*G8/2./32.2*V8*((1.-SIGMA*SIGMA)*(V9/V8-1.)+AF89*A/AC
     1*V89M/V8)*ANP/3600./3600.
      DPB2 = 3.54/62.4/1.E+6 *GB*GB*V1011M*ANB
      DPB = DPB1+DPB2
      DPB  = DPB /144.
C
C  TUBE SIDE PRESSURE DROP                        - PSIA
      DTF   = DT/12.
      DPT =(AF10+AF11)/2.*V1011M*TL/DTF*G10*G10/32.2/2./3600./3600.
      DPT = DPT/144.
C
C  CATALYST BED PRESSURE DROP
      VBED   = 3.1416 *DBED *DBED /4. *ALBED
      ANS   =  ALBED/2./DW
      AFRS   = 3.1416 *DBED *DBED /4.
      ACOAF = ((1./AMESH -DW)*AMESH )**2.
```

Figure B-20. (Continued) (Sheet 2 of 3)

```
      ACBED = AFRS *ACOAF
      GBED = WV/ACBED*144.
      AWIRE = 6.2832*DW * AFRS *AMESH *ANS
      VWIRE = AWIRE *DW /4.
      PBED = 1.-VWIRE/VBED
      ALPHA = AWIRE /VBED
      RHBED =PBED/ALPHA/12.
      RNBED =4.*RHBED*GBED/AMU10
      CALL LAGIN2 (809,REB,NREB,2,RNBED,AFBED,REBEDF)
      DPC =GBED*GBED * V10 *AFBED *AWIRE/ACBED /2./32.2/3600./3600./144.
C
C  OVERALL UA FOR RECUPERATOR
      HINNER = (AH8+AH9)/2.
      HOUTER = (AH10+AH11)/2.
      ATUBE =3.1416 *DT /12. *ANT * TL
      AOUT   =ATUBE * (DT +.005)/DT
      AAVG  = (AOUT + ATUBE)/2.
      ANVU  = 1./HINNER +.005/12./AAVG*ATUBE +1./AOUT/HOUTER *ATUBE
      UAA   =  ATUBE/ANVU
      CM1N  = WV * (CP8+CP10)/2.
      ANTU  = UAA/CM1N
      ALAMDA= AKC *ARXC /TL /CM1N
      A1     = 1.+ ALAMDA * ANTU
      A2     = ALAMDA *ANTU /A1
      AI     = 1./(1.+ANTU *(1.+ALAMDA *A2**.5 )/A1)
      EFFH   = 1. - AI
      NCALC = NCALC + 1
      IF (NCALC.LE.1) GO TO 100
  500 T(9) = T9G
      T(11) = T11G
      P(9)  = P9G
      P(10) = P10G
      P(11) = P11G
C  POWER TO OVERCOME INEFFICTIVENESS
      POWC  =   (T(10) -T(9))*WV *CP10 /3.41
      QL(10) = ((T(10)+T(11))/2. -T(20)) * UA(10)
C  TOTAL POWER                                       -  WATTS
      PREC = POWC + QL(10)/3.41
      GO TO 1000
  700 IF(IPRINT.NE.2) GO TO 1000
      CALL PRINTG (T(8),P(8),T(11),P(11),EFFH,DPB,QL(10),DPT,PREC,T(9),
     1DPC,P(9),IPRINT)
 1000 RETURN
      END
```

Figure B-20. (Continued) (Sheet 3 of 3)

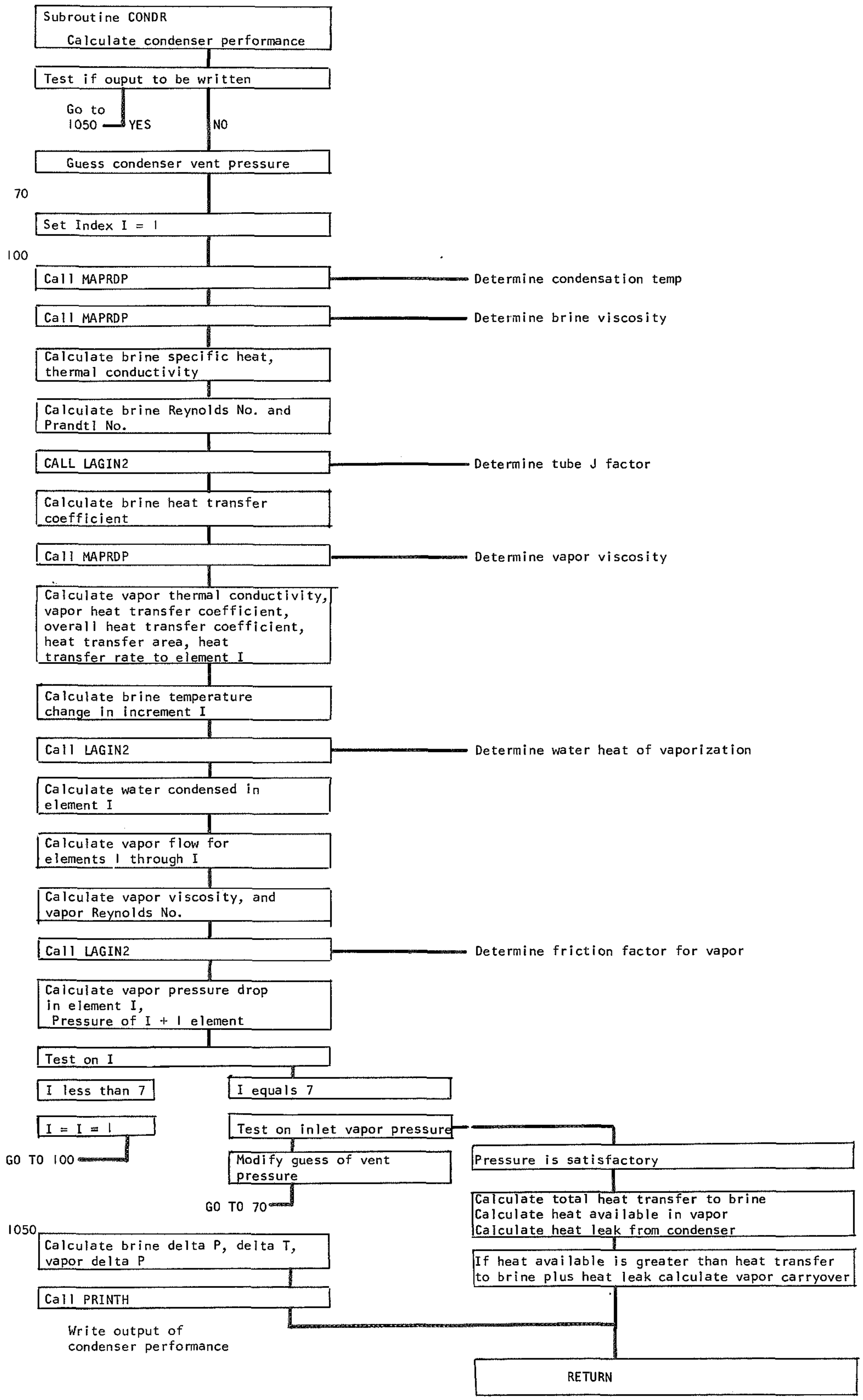


Figure B-21. Block Diagram of CONDR

@ ELT CONDR,1,701211, 38493 , 1

```
      SUBROUTINE CONDR (CO,WBRIN,WVV,QBRIN,PCOND)
C     SUBROUTINE FOR DETERMINING THE PERFORMANCE OF THE CONDENSER/BRINE
C     HEATER
C     THIS PROGRAM CALCULATES THE CONDENSER PRESSURE REQUIRED FOR COUPLE
C     TE CONDENSATION, ALSO BRINE HEAT TRANSFER AND HEAT LEAK
      COMMON/GENRLD/ T(20),UA(20),P(20),QL(20),D(20),AL(20),REN(40),
     1NREN,JREN(40),RELL(40),NREL,FANFR(40),KPRINT,IPRINT
      COMMON/UPROP/TP(65),CP(20),PP(65,20),NTP,NCP,TH(43),HH(43),
     1NTH,CU(20),TV(65),VISB(65,20),NTV,NCV
      COMMON/CONDD/VPC(10),VTC(10),BTC(10),ALHX(10),DSEP(10),AFOUL,
     1TKSS,WVO
      DIMENSION WV(10),QB(10),DPV(10)
      IF(KPRINT.EQ.1) GO TO 1050
      PI=3.14159
      KK2 =0
      KK1 = 0
      KLOOP = 0
      DPCOND = .02*P(12)
      XP    =  1./64.4/3600./3600./144.
      BTC(1) = T(3)
      DO    =(D(11)+.0016)/12
      DI    = D(11)/12.
   50 PGUESS = P(12)
   70 I = 1
   80 VPC(I) = PGUESS
      SUMQB = 0.
      SUMWV = 0.
  100 CALL MAPRDP (701,CP,TP,PP,NCP,NTP,2,2,0.,VTC(I),VPC(I),2)
      CALL MAPRDP (702,CU,TV,VISB,NCV,NTV,2,2,CO,BTC(I),AU,1)
      AKBRIN = 0.347*(1-.0015*(BTC(I)-100.))*(1. -.576*CO/(1.69-CO))
      CPBRIN = 1. -.7* CO
C
C  AKBRIN IN BTU/HR/FT/R  CPBRIN IN BTU/LB/R  MU IN
C
C  CALCULATE REYNOLDS NO FOR BRINE
  200 XREN=4.*WBRIN/3.1416/DI/AU/2.4323
C  LOOK UP J FACTOR
      CALL LAGIN2 (701,REN,NREN,2,XREN,XJ,JREN)
C  CALCULATE BRINE HT TRANSFER COEFF
      PRB = AU*CPBRIN/AKBRIN
      PRB=PRB*2.42
      IF(PRB.LE.0.) GO TO 340
      HB=4.*WBRIN*CPBRIN*XJ/3.1416/DI/DI/PRB**.667
C
C  CALCULATE STEAM CONDENSING COEFFICIENT
      AKWAT=.347*(1.+.0015*(VTC(I)-100.))
      TSTM = BTC(I) + 0.2 * (VTC(I)-BTC(I))
      CALL MAPRDP (703,CU,TV,VISB,NCV,NTV,2,2,0.,VTC(I),AUW,1)
      IF(VTC(I).LE.TSTM) GO TO 320
      HS = .725*(62.43*4.17*10.**8*1020.*AKWAT**3/AUW/DO/(VTC(I)-TSTM))*
     1*.25
C
C  CALCULATE THE OVERALL HEAT TRANSFER COEFF
C
      UINV =  DO /DI/ HB + 1./HS + AFOUL + DO*ALOG(DO/DI)/2./TKSS
      U = 1./UINV
      GO TO 340
  320 U = 0.
  340 AHT=PI*DO*ALHX(I)
      AHT = AHT/12.
  350 QB(I)=U*AHT   *(VTC(I)-BTC(I))
      DELTB = QB(I)/WBRIN/CPBRIN
C
C  LATENT HEAT OF STEAM
      CALL LAGIN2 (702,TH,NTH,2,VTC(I),HLV,HH)
C  VAPOR FLOW RATE
  400 WV(I) = QB(I)/HLV
  450 SUMQB = SUMQB+QB(I)
      IF (SUMWV +WV(I).GT.WVV) WV(I) = WVV-SUMWV
      SUMWV=SUMWV+WV(I)
```

Figure B-22. CONDR Listing (Sheet 1 of 2)

```
      C  VAPOR PRESSURE DROP
        500 UVAP = 1.81 + 0089 *(VTC(I)**.88)*.0322 * .36
            AF = DO * (DSEP(I)+DO)-3.1416*DO*DO*.25
            WP = 2.*(DSEP(I) + DO) + 3.1416*DO
            RH = AF/WP
            WVDP = SUMWV-WV(I)/2.
            ROV = VPC(I)/85.8/(VTC(I)+460.)*144.
            GV = WVDP/AF
            REV = 4.*RH*GV/UVAP
            CALL LAGIN2 (703,RELL,NREL,2,REV,FAV,FANFR)
            DPV(I) = FAV*ALHX(I)*GV*GV/RH/ROV*XP/12.
        550 VPC(I+1) = VPC(I)+DPV(I)
            BTC(I+1) = BTC(I)+DELTB
            IF(I.GE.7) GO TO 600
            I= I+1
            GO TO 100
        600 DPC = VPC(8)-P(12)
            KLOOP = KLOOP+1
            IF(KLOOP.GT.20) GO TO 1100
            IF(ABS(DPC/P(12)).LE..002) GO TO 640
            IF(VPC(8).LT.P(12)) GO TO 620
            IF(KK1.EQ.1.AND.KK2.EQ.1) DPCOND = DPCOND*.5
            KK1=1
            PGUESS = PGUESS-DPCOND
            GO TO 70
        620 IF(KK1.EQ.1.AND.KK2.EQ.1) DPCOND=DPCOND*.5
            KK2=1
            PGUESS = PGUESS+DPCOND
            GO TO 70
        640 QL(11) = UA(11)*(VTC(3)-T(20))
            AVAPT =(T(12) + VTC(7))/2.
            CPVA = 0.46 + .048*(AVAPT-300.)/700.
            QVAP = CPVA * SUMWV * (T(12)-VTC(7))
            QLIQ = SUMWV * HLV
            QAVAIL = QVAP+QLIQ-QL(11)
            DQHX = QAVAIL-SUMQB
            WVO = DQHX/HLV
            IF(WVO.LE.0.) WVO=0.
       1000 T(4) = T(3)+SUMQB/CPBRIN/WBRIN
            P(18) = VPC(1)
            QBRIN = SUMQB
            GO TO 1200
       1050 IF(IPRINT.NE.2) GO TO 1200
            BDP=P(3)-P(4)
            VDP = VPC(8) - VPC(1)
            BDT=T(4)-T(3)
            CALL PRINTH(WBRIN,WVV,BDP,P(12),BDT,VDP,HB,VTC(1),T(3),HS,QL(11),
           1IPRINT)


            GO TO 1200
       1100 WRITE(6,1) QL(11),SUMQB,QAVAIL,SUMWV,PGUESS,P(18)
          1 FORMAT(10X,'P NOT CONVERGED IN CONDR'/10X,'QL(11)=',F10.4,'SUMQB =
           1',F10.4,'QAVAIL =',F10.4,'SUMWV =',F10.4/10X,'PGUESS =',F10.4
           1,'P(18) =',F10.4)
            GO TO 640
       1200 RETURN
            END
```

Figure B-22. (Continued) (Sheet 2 of 2)

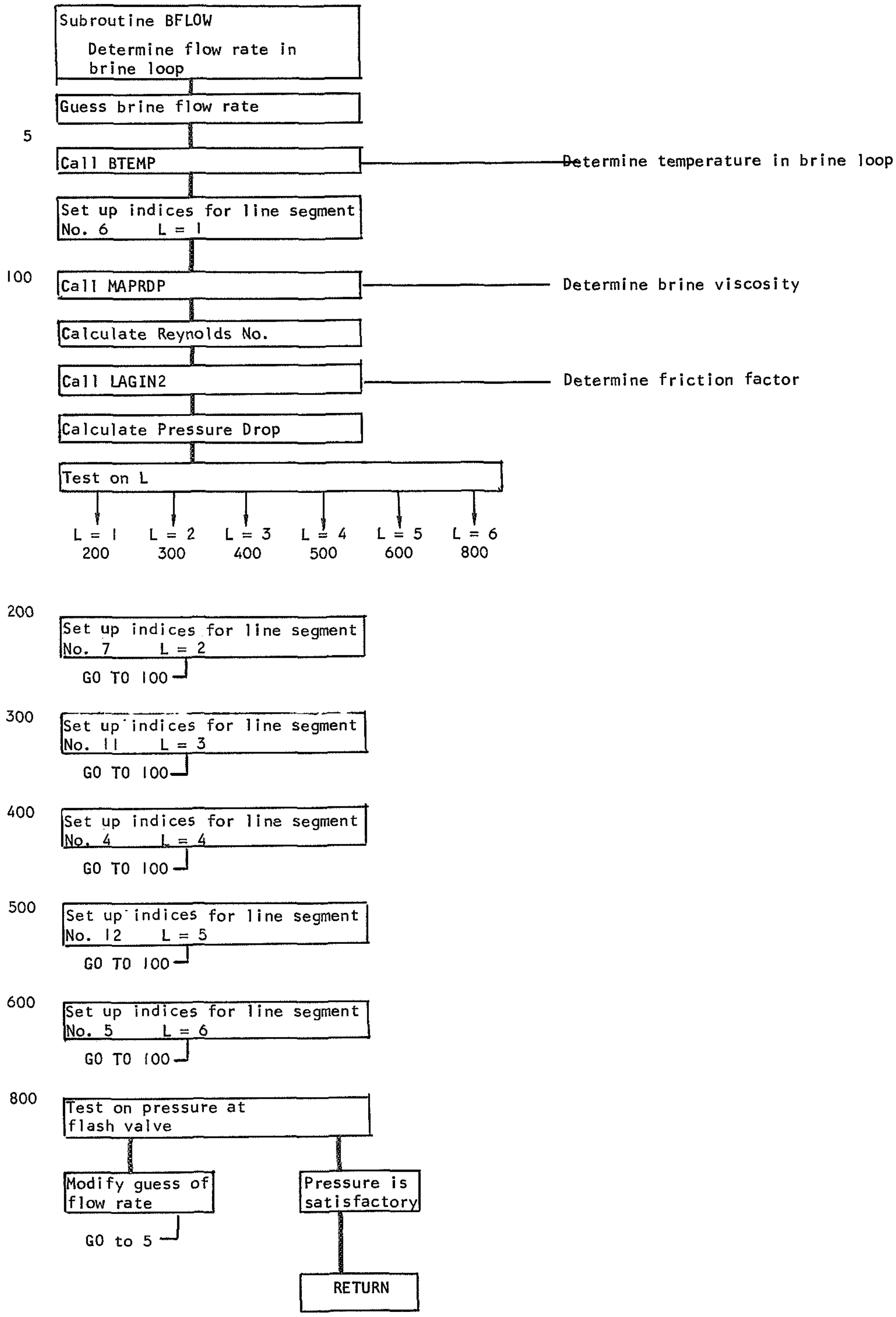


Figure B-23. Block Diagram of BFLOW

@ ELT BFLOW,1,701211, 38497   , 1

```
              SUBROUTINE BFLOW
      C  CALCULATES BRINE FLOW RATE
              COMMON/BFLOWD/WBRIN,CO,KDUMP,WDUMP
              COMMON/UPROP/TP(65),CP(20),PP(65,20),NTP,NCP,TH(43),HH(43),
             1NTH,CU(20),TV(65),VISB(65,20),NTV,NCV
              COMMON/GENRLD/ T(20),UA(20),P(20),QL(20),D(20),AL(20),REN(40),
             1NREN,JREN(40),RELL(40),NREL,FANFR(40),KPRINT,IPRINT
              COMMON/BTEMPD/KFEED,KHEAT,QHEAT,WFEED,CONF
      C  SUBSCRIPTS  I = NUMBER OF INCREMENT  J= BEGINNING POSITION K = END POSITION
      C              I = 9  PITOT TO SEP OUTLET  J =  2      K = 17
      C              I = 6  SEP OUTLET TO DUMP   J = 17      K = 16
      C              I = 7  DUMP TO HEAT EX      J = 16      K =  3
      C              I =10  HEAT EX TUBE         J =  3      K =  4
      C              I = 4  HEAT EX TO FEED      J =  4      K = 14
      C              I = 8  TRIM HEATER          J = 14      K = 15
      C              I = 5  TRIM HEATER TO VALVE J = 15      K =  1
              IF(KPRINT.EQ.1) GO TO 1000
              K1 =0
              KCOUNT = 0
              K2 =0
              DW  = .1*WBRIN
              WBR = WBRIN
            5 CALL BTEMP (WBR , CO)
              PSAT = P(5)
              PCONV = 3.
           50 I  =  6
              J= 2
              K=17
              L= 1
          100 TBAR = (T(J) + T(K))/2.
              CALL MAPRDP (302,CU,TV,VISB,NCV,NTV,2,2,CO,TBAR,AU,1)
      C  DIMENSIONS    - D   -  INCHES     L - FEET    MU  -  CP    WBR - LB/HR
              RE = 4.*WBR/3.1416/AU/D(I)/.20159
              CALL LAGIN2 (301, RELL,NREL,2,RE,FA,FANFR)
              RHOB = (.4775 *CO   +.99325 )* 62.43
              DPOL=FA*2.*WBR*WBR/(3.1416*3.1416*D(I)**5*RHOB)*.0000663
              P(K) = P(J) - DPOL *AL(I)
              GO TO (200,300,400,500,600,800),L
          200  I = 7
              J = 17
              K=3
              L = 2
              GO TO 100
          300 CONTINUE
              I=11
              J=3
              K=4
              L =  3
              GO TO 100
          400  I=  4
               J= 4
              K=14
              L = 4
              GO TO 100
          500 I=12
              J=14
              K=15
              L = 5
```

Figure B-24. BFLOW Listing   (Sheet 1 of 2)

```
      GO TO 100
  600 CONTINUE
  650 I=5
      J=15
      K=1
      L = 6
      GO TO 100
  800 ERP = P(1) -PCONV
      KCOUNT = KCOUNT +1
      IF(KCOUNT.EQ.20) GO TO 900
      IF (ABS(ERP/PCONV).LT. .01) GO TO 1000
      IF (ERP.LT. 0.) GO TO  850
      K1 = 1
      IF (K1.EQ.1.AND.K2.EQ.1)DW =DW * .5
      WBR=WBR+DW
      GO TO 5
  850 K2=1
      IF (K1.EQ.1.AND.K2.EQ.1) DW = DW *.5
      WBR=WBR-DW
      GO TO 5
  900 WRITE(6,1) WBR,PCONV,P(1)
    1 FORMAT(10X,'BRINE FLOW NOT CONV IN BFLOW'/13X,'WBR =',F10.4,'PCONV
     1=',F10.4,'P(1) =',F10.4)
 1000 WBRIN=WBR
      CALL BTEMP (WBR,CO)
      RETURN
      END
```

Figure B-24. (Continued) (Sheet 2 of 2)

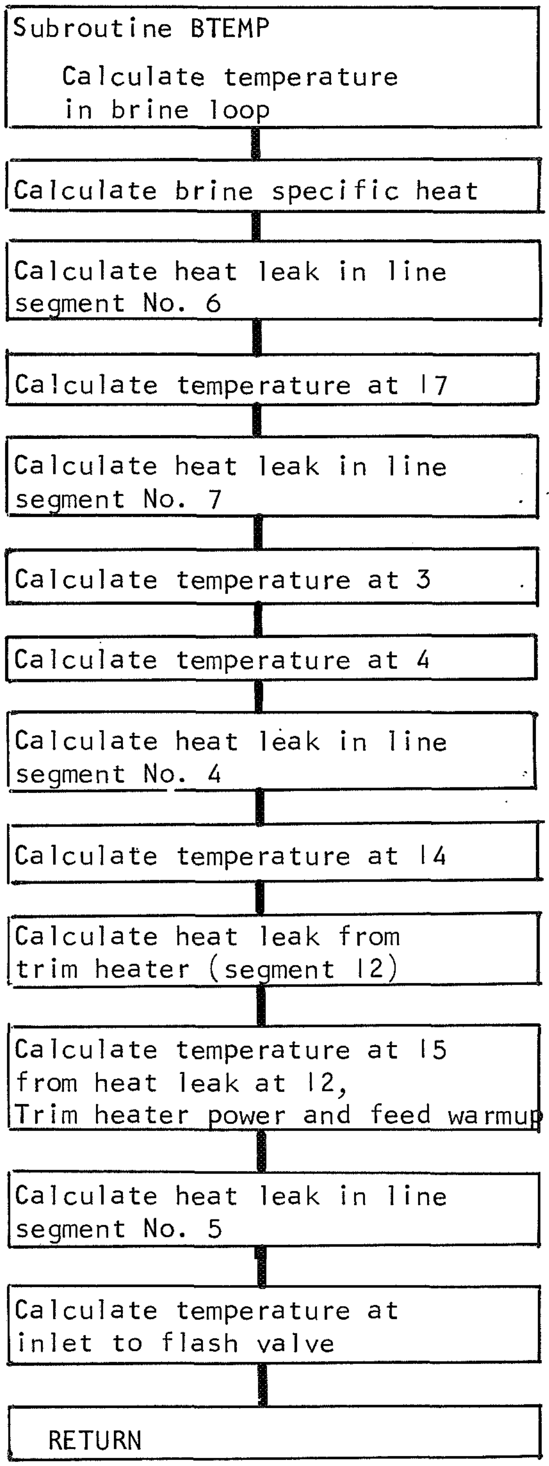


Figure B-25. Block Diagram of BTEMP

```
@ ELT BTEMP,1,701214, 60873    , 1
      SUBROUTINE BTEMP (WBRIN,CONC)
      COMMON/UPROP/TP(65),CP(20),PP(65,20),NTP,NCP,TH(43),HH(43),
     1NTH,CU(20),TV(65),VISB(65,20),NTV,NCV
C  THIS SUBROUTINE CALCULATES THE NET HEAT BALANCE ON THE BRINE
C  FEED FOR FEED AND NO FEED, HEATER ON OR OFF
      COMMON/GENRLD/ T(20),UA(20),P(20),QL(20),D(20),AL(20),REN(40),
     1NREN,JREN(40),RELL(40),NREL,FANFR(40),KPRINT,IPRINT
      COMMON/BTEMPD/KFEED,KHEAT,QHEAT,WFEED,CONF
      CPFED = 1.-.7*CONF
      BDTC = T(4) - T(3)
  130 QL(6) = UA(6)*(T(2)-T(20))
      CPBRIN = 1.-.7*CONC
      T(17) = T(2) - QL(6)/(CPBRIN*WBRIN)
      QL(7) = UA(7)*(T(17)-T(20))
      T(3) = T(17) - QL(7)/(CPBRIN*WBRIN)
      T(4) = T(3)+BDTC
      QL(4) = UA(4)*(T(4)-T(20))
      T(14) = T(4) - QL(4)/(CPBRIN*WBRIN)
      QL(12) = UA(12)*(T(14)-T(20))
      T(15) = T(14) - QL(12)/(CPBRIN*WBRIN)
      T(15)=T(15)-KFEED*WFEED*CPFED*(T(14)-T(19))/WBRIN/CPBRIN
      T(15) = T(15)+KHEAT*QHEAT*3.41/WBRIN/CPBRIN
      QL(5) = UA(5)*(T(15)-T(20))
      T(1) = T(15)- QL(5)/(CPBRIN*WBRIN)
      GO TO 1000
 1000 RETURN
      END
```

2. LIST PDVAP

Figure B-26. BTEMP Listing

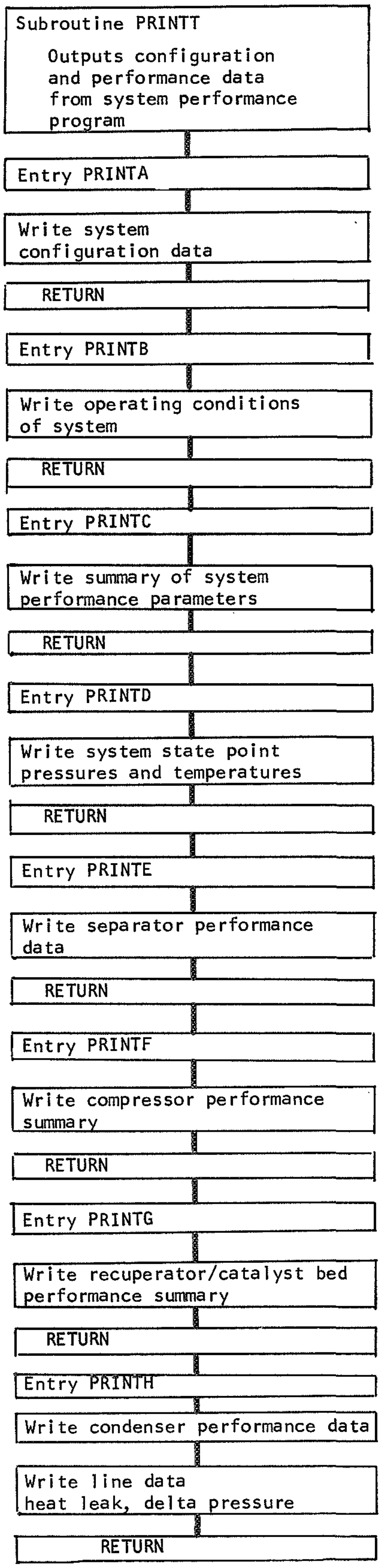


Figure B-27. Block Diagram of PRINTT

@ ELT PRINTT,1,701211, 38487 , 1

```
      SUBROUTINE PRINTT
      COMMON/GENRLD/ T(20),UA(20),P(20),QL(20),D(20),AL(20),REN(40),
     1NREN,JREN(40),RELL(40),NREL,FANFR(40),KPRINT,IPRINT
      COMMON/PRINTX/TLHX
      COMMON/COMPRD/VFLO(20),NPR   ,PRC(20),POWC(20),POW ,TB   ,PB,PE
      COMMON/CONDD/VPC(10),VTC(10),BTC(10),ALHX(10),DSEP(10),AFOUL,
     1TKSS,WVO
      COMMON/SEPRD/OMEGA,DD,CD,DL,AK,PTR,SMV,POWS
      COMMON/RECUPD/ AC,AF,AB,TL,DT,ANT,ANP,AKC,ARXC,DBED,DW,ALBED,
     1AMESH,EFFH,DPC,DDT,DPB,RET(50),RETF(50),RETJ(50),NREJ,
     2RES(50),RESF(50),RESJ(50),NRES,REB(50),REBEDF(50),NREB
      DIMENSION DP(20),HEAD(20)
C     THIS SUBROUTINE IS USED TO PRINT ALL OF THE DATA FROM URECU
      ENTRY PRINTA (HEAD,IPRINT)
C     THIS ENTRY IS FOR LISTING SYSTEM CONFIGURATION DATA
      WRITE (6,1) HEAD
      WRITE(6,2) DD,AK,DL,CD,PTR,SMV,UA(8)
      WRITE (6,3) UA(9)
      WRITE (6,4)(VFLO(I),PRC(I),POWC(I),I=1,NPR)
      TF = TL*12.
      WRITE (6,5) ANT,AC,ANP,AF,TF,AB,DT,ARXC,UA(10),AKC
      WRITE (6,6) ALBED,DW,DBED,AMESH
      WRITE (6,7) TLHX,AFOUL,D(11),UA(11)
      WRITE (6,8)  AL(4),D(4),UA(4)
      WRITE (6,9) AL(5),D(5),UA(5)
      WRITE (6,10) AL(6),D(6),UA(6)
      WRITE (6,11) AL(7),D(7),UA(7)
      WRITE (6,12) AL(1),D(1),UA(1)
      WRITE (6,13) AL(2),D(2),UA(2)
      WRITE (6,14) AL(3),D(3),UA(3)
    1 FORMAT (1H1, 9X,20A4/)
    2 FORMAT (10X,'CONFIGURATION DATA '//10X,'SEPARATOR '/28X,'ROTATING
     1DRUM WITH PITOT TUBE LIQUID PICKUP'//
     218X,'DRUM DIAMETER          =',F10.4,' INCHES',13X,
     3'PITOT HEAD COEFFICIENT     =',F10.4/
     418X,'DRUM LENGTH            =',F10.4,' INCHES',13X,
     5'PITOT DRAG COEFFICIENT     =',F10.4/
     618X,'PITOT TUBE RADIUS      =',F10.4,' INCHES',13X,
     7'MINIMUM SEPARATOR VOLUME   =',F10.4,' CU.IN.'/
     818X,'HEAT LEAK TO AMBIENT   =',F10.4,' BTU/HR/F'/)
    3 FORMAT (10X,'COMPRESSOR '/28X,'TWO STAGE VORTEX WITH SINGLE SIDED
     1WHEELS'//
     218X,'HEAT LEAK TO AMBIENT   =',F10.4,'  BTU/HR/F'/26X,'FLOW(CFM)',
     310X,'PRESS RATIO',7X,'POWER(WATTS)')
    4 FORMAT (15X,3F20.4)
    5 FORMAT (/10X,'RECUPERATOR '/28X,'CROSS-COUNTER FLOW SHELL TUBE EXC
     1HANGER WITH INLET ON SHELL SIDE'//
     218X,'NUMBER OF TUBES        =',F10.4,20X,
     3'FLOW AREA ON SHELL SIDE    =',F10.4,' FT-FT'/
     418X,'NUMBER OF PASSES       =',F10.4,20X,
     5'FRONTAL AREA SHELL SIDE    =',F10.4,' FT-FT'/
     618X,'TUBE LENGTH            =',F10.4,' INCHES',13X,
     7'BAFFLE FLOW AREA           =',F10.4,' FT-FT'/
     818X,'TUBE DIAMETER          =',F10.4,' INCHES',13X,
     9'AXIAL CONDUCTION AREA      =',F10.4,' FT-FT'/
     A18X,'HEAT LEAK TO AMBIENT   =',F10.4,' BTU/HR/F',11X,
     B'AXIAL COND CONDUCTIVITY    =',F10.4,' BTU/HR/FT/F'/)
    6 FORMAT (10X,'CATALYST BED '/28X,'WIRE MESH CATALYST BED WITH FLOW
     1ALONG AXIS'//
     218X,'BED LENGTH             =',F10.4,' INCHES',13X,
     3'WIRE DIAMETER              =',F10.4,' INCHES'/
     418X,'BED DIAMETER           =',F10.4,' INCHES',13X,
     5'MESH SIZE                  =',F10.4,' WIRES/IN'/)
    7 FORMAT (10X,'CONDENSER '/28X,'SPIRAL TUBE HX-BRINE ON INSIDE-STEAM
     1ON OUTSIDE -COUNTER FLOW'//
     218X,'TUBE LENGTH            =',F10.4,' INCHES',13X,
     3'FOULING FACTOR             =',F10.4/
     418X,'TUBE DIAMETER          =',F10.4,' INCHES',13X,
     5'HEAT LEAK TO AMBIENT       =',F10.4,'  BTU/HR/F'//10X,'FLUID LINES
     6'/50X,'LENGTH(FT)',9X,'DIAMETER(IN)',8X,'UA(BTU/HR/F)'/16X,'BRINE
```

Figure B-28. PRINTT Listing (Sheet 1 of 3)

```
        7LINES')
       8 FORMAT (18X,'CONDENSER TO FEED    ',3F20.4)
       9 FORMAT (18X,'FEED TO SEPARATOR   ',3F20.4)
      10 FORMAT (18X,'SEPARATOR TO DUMP   ',3F20.4)
      11 FORMAT (18X,'DUMP TO CONDENSER   ',3F20.4/16X,'VAPOR LINES')
      12 FORMAT (18X,'SEPARATOR TO COMPRESSOR        ',F10.4,2F20.4)
      13 FORMAT (18X,'COMPRESSOR TO RECUPERATOR      ',F10.4,2F20.4)
      14 FORMAT (18X,'RECUPERATOR TO CONDENSER       ',F10.4,2F20.4)
         RETURN
         ENTRY PRINTB (B1,B2,B3,B4,IPRINT,B5,B6)
C        THIS ENTRY IS FOR LISTING OPERATING CONDITIONS OF SYSTEM
         B2P = B2*100.
         B3P = B3*100.
         WRITE(6,20) B1,T(20),B2P,T(19),B3P,B5,T(10)
      20 FORMAT (1H1,10X,'PERFORMANCE DATA'//16X,'OPERATING CONDTIONS '/
        118X,'SEPARATOR LEVEL        =',F10.4,' CU.IN',14X,
        2'AMBIENT TEMPERATURE      =',F10.4,' DEG F'/
        318X,'BRINE CONCENTRATION    =',F10.4,' PERCENT SOLIDS',5X,
        4'FEED TEMPERATURE         =',F10.4,' DEG F'/
        518X,'FEED CONCENTRATION     =',F10.4,' PERCENT SOLIDS',5X,
        6'VENT PRESSURE            =',F10.4,' PSIA'/
        718X,'CATALYST TEMPERATURE  =',F10.4)
         RETURN
         ENTRY PRINTC (C1,C2,C3,C4,C5,C6,IPRINT,C7,C8)
         WRITE (6,30) C1,C4,P(5),C5,C2,C6,C3,WVO
      30 FORMAT (/16X,'SYSTEM PERFORMANCE SUMMARY '/
        118X,'WATER PROD. RATE       =',F10.4,' LB/HR',14X,
        2'SEPARATOR POWER          =',F10.4,' WATTS'/
        318X,'SEPARATOR PRESSURE     =',F10.4,' PSIA',15X,
        4'COMPRESSOR POWER         =',F10.4,' WATTS'/
        518X,'COMPRESSOR PRESS RATIO=',F10.4,20X,
        6'CATALYST/RECUP. POWER    =',F10.4,' WATTS'/
        718X,'BRINE FLOW RATE        =',F10.4,' LB/HR',14X,
        8 'VAPOR CARRYOVER          =',F10.4,' LB/HR'/)
         RETURN
         ENTRY PRINTD (IPRINT)
         WRITE (6,40)
      40 FORMAT(/10X,'SYSTEM STATE POINTS ',40X,'PRESSURE(PSIA)',7X,'TEMPER
        1ATURE(DEG F)')
         WRITE (6,41) P(1),T(1)
         WRITE (6,42) P(2),T(2)
         WRITE (6,43) P(3),T(3)
         WRITE (6,44) P(4),T(4)
         WRITE (6,45) P(5),T(5)
         WRITE (6,46) P(6),T(6)
         WRITE (6,47) P(7),T(7)
         WRITE (6,48) P(8),T(8)
         WRITE (6,49) P(9),T(9)
         WRITE (6,50) P(10),T(10)
         WRITE (6,51) P(11),T(11)
         WRITE (6,52) P(12),T(12)
      41 FORMAT (18X,'1    INLET TO FLASH VALUE          ',6X,2F22.4)
      42 FORMAT (18X,'2    OUTLET OF PITOT TUBE          ',6X,2F22.4)
      43 FORMAT (18X,'3    BRINE INLET TO CONDENSER      ',6X,2F22.4)
      44 FORMAT (18X,'4    BRINE OUTLET FROM CONDENSER ',6X,2F22.4)
      45 FORMAT (18X,'5    SEPARATOR VAPOR OUTLET        ',6X,2F22.4)
      46 FORMAT (18X,'6    INLET TO COMPRESSOR           ',6X,2F22.4)
      47 FORMAT (18X,'7    OUTLET OF COMPRESSOR          ',6X,2F22.4)
      48 FORMAT (18X,'8    RECUPERATOR INLET             ',6X,2F22.4)
      49 FORMAT (18X,'9    CATALYST BED INLET            ',6X,2F22.4)
      50 FORMAT (18X,'10   CATALYST BED OUTLET           ',6X,2F22.4)
      51 FORMAT (18X,'11   RECUPERATOR OUTLET            ',6X,2F22.4)
      52 FORMAT (18X,'12   CONDENSER VAPOR INLET         ',6X,2F22.4)
         RETURN
         ENTRY PRINTE (E1,E2,E3,E4,E5,E6,E7,E8,IPRINT)
         WRITE (6,53) E1,E2,E3,E4,E5,E6
      53 FORMAT (//10X,'COMPONENT PERFORMANCE DATA '//16X,'SEPARATOR '/
        118X,'SPEED             =',F10.4,' RPM',
        216X,'BRINE OUTLET PRES=',F10.4,' PSIA'/
        318X,'POWER             =',F10.4,' WATTS',
        414X,'BRINE TEMPERATURE=',F10.4,' DEG F'/
        518X,'VAPOR PRESSURE    =',F10.4,' PSIA',
```

Figure B-28. (Continued)   (Sheet 2 of 3)

```
      615X,'HEAT LEAK         =',F10.4,' BTU/HR')
  550 RETURN
      ENTRY PRINTF (F1,F2,F3,F4,F5,F6,F7,F8,IPRINT)
      WRITE (6,60) F1,F2,F3,F4,F5,F6,F7,F8
   60 FORMAT (//10X,'COMPONENT PERFORMANCE DATA '//16X,'COMPRESSOR '/
     118X,'INLET PRESS       =',F10.4,' PSIA',
     215X,'POWER             =',F10.4,' WATTS'/
     318X,'OUTLET PRESS      =',F10.4,' PSIA',
     415X,'ADIABATIC EFF.    =',F10.4,' PERCENT'/
     518X,'PRESS RATIO       =',F10.4,
     620X,'HOUSING TEMP.     =',F10.4,' DEG F'/
     718X,'VOLUME FLOW       =',F10.4,' CFM',
     816X,'HEAT LEAK         =',F10.4,' BTU/HR')
  650 RETURN
      ENTRY PRINTG (G1,G2,G3,G4,G5,G6,G7,G8,G9,G10,G11,G12,IPRINT)
      WRITE (6,70) G1,G2,G3,G4,G5,G6,G7,G8,G9,G10,G11,G12
   70 FORMAT (//10X,'COMPONENT PERFORMANCE DATA '//16X,'RECUPERATOR '/
     118X,'INLET TEMP.       =',F10.4,' DEG F',
     214X,'INLET PRESS.      =',F10.4,' PSIA'/
     318X,'OUTLET TEMP.      =',F10.4,' DEG F',
     414X,'OUTLET PRESS.     =',F10.4,' PSIA'/
     518X,'EFFECTIVENESS     =',F10.4,
     620X,'SHELL SIDE DEL P  =',F10.4,' PSID'/
     718X,'HEAT LEAK         =',F10.4,' BTU/HR',
     813X,'TUBE SIDE DEL P   =',F10.4,' PSID'/
     918X,'POWER             =',F10.4,' WATTS'//16X,'CATALYST BED '/
     A18X,'INLET TEMP.       =',F10.4,' DEG F',
     B14X,'BED DELTA P       =',F10.4,' PSID'/
     C18X,'INLET PRESS.      =',F10.4,' DEG F')
  750 RETURN
      ENTRY PRINTH (H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,IPRINT)
      WRITE (6,80) H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11
   80 FORMAT (//10X,'COMPONENT PERFORMANCE DATA '//16X, 'CONDENSER '/
     118X,'BRINE FLOW        =',F10.4,' LB/HR',
     214X,'VAPOR FLOW        =',F10.4,' LB/HR'/
     318X,'BRINE DELTA P     =',F10.4,' PSID '
     414X,'VAPOR INLET P     =',F10.4,' PSIA '/
     518X,'BRINE DELTA T     =',F10.4,' DEG F',
     614X,'VAPOR DELTA P     =',F10.4,' PSID '/
     718X,'BRINE H           =',F10.4,' BTU/HR/FT/FT/F',
     8 5X,'VAPOR SATUR T     =',F10.4,' DEG F'/
     918X,'BRINE INLET T     =',F10.4,' DEG F',
     A14X,'VAPOR H           =',F10.4,' BTU/HR/FT/FT/F'/
     B18X,'HEAT LEAK         =',F10.4,' BTU/HR')
      ENTRY PRINTI (IPRINT)
      DP(4) = P(4) - P(14)
      DP(5) = P(15)- P(1)
      DP(6) = P(2) - P(17)
      DP(7) = P(17) - P(3)
      DP(1) = P(5) - P(6)
      DP(2) = P(7) - P(8)
      DP(3) = P(11)- P(12)
      WRITE (6,90)
      WRITE (6, 8) DP(4), QL(4)
      WRITE (6, 9) DP(5), QL(5)
      WRITE (6,10) DP(6), QL(6)
      WRITE (6,11) DP(7), QL(7)
      WRITE (6,12) DP(1), QL(1)
      WRITE (6,13) DP(2), QL(2)
      WRITE (6,14) DP(3), QL(3)
   90 FORMAT (//10X,'LINE DATA'/40X,'PRESSURE DROP(PSID)   HEAT LEAK(BTU
     1/HR)')
      END
```

Figure B-28. (Continued) (Sheet 3 of 3)

```
@ ELT UREAD,1,701211, 38500    , 1
      SUBROUTINE UREAD
C     READING SUBROUTINE FOR VAPOR PRESSURE AND HEAT OF VAPORIZATION OF
C     URINE CONCENTRATES
      COMMON/UPROP/TP(65),CP(20),PP(65,20),NTP,NCP,TH(43),HH(43),
     1NTH,CU(20),TV(65),VISB(65,20),NTV,NCV
C  TP  =   TEMPERATURE ARRAY FOR VAPOR PRESSURE CURVES
C  CP  =   CONCENT     ARRAY FOR VAPOR PRESSURE CURVES
C  PP  =   PRESSURE    ARRAY FOR VAPOR PRESSURE CURVES -PP(NTP,NCP)
C  NTP =   NUMBER OF TEMPS. IN VAPOR PRES. ARRAY
C  NCP =   NUMBER OF CONCS. IN VAPOR PRES. ARRAY
      READ (5,1) NTH
      READ (5,2) (TH(I),I=1,NTH)
      READ (5,2) (HH(I),I=1,NTH)
   10 READ (5,1) NTP,NCP
      READ (5,2)(TP(I),I=1,NTP)
      READ (5,2)(CP(I),I=1,NCP)
      DO 50 I=1,NTP
   50 READ (5,2)(PP(I,J),J=1,NCP)
      READ (5,1) NTV,NCV
      READ (5,2) (TV(I),I=1,NTV)
      READ (5,2) (CU(I),I=1,NCV)
      DO 60 I=1,NTV
   60 READ (5,2)(VISB(I,J),J=1,NCV)
  100 RETURN
    1 FORMAT (8I10)
    2 FORMAT (8F10.0)
      END
```

Figure B-29. UREAD Listing

```
@ ELT MAPRDP,1,701211, 38496    , 1
      SUBROUTINE MAPRDP (ID,C,T,P,NC,NT,NDC,NDP,CA,TA,PA,K)
C  SUBROUTINE FOR READING MAP  GIVEN X,Y,FIND Z,GIVEN X,Z,FIND Y
      DIMENSION C(20),T(65),P(65,20)
C  ID = LOOKUP IDENTIFICATION
C  C  = INDEPENDENT VARIABLE ARRAY
C  T  = INDEPENDENT VARIABLE ARRAY
C  P  = DEPENDENT   VARIABLE ARRAY
C  NC = NO. OF ELEMENTS IN X ARRAY
C  NT = NO. OF ELEMENTS IN Y ARRAY
C  NDC= NO. OF POINTS IN INTERPOLATION
C NDT== NO. OF POINTS IN INTERPOLATION
C  CA = VALUE OF X    -INPUT
C  TA = VALUE OF Y    -INPUT IF  K= 0
C  PA = VALUE O  Z    -INPUT FF  K= 1
C  K  = 1,2  FOR X,Y INDEPENDENT , X,Z INDEPENDENT RESPECTIVELY
   10 IF(CA.GT.C(1)) GO TO 50
      I = 2
      GO TO 120
   50 IF(CA.LT.C(NC)) GO TO 100
      I = NC
      GO TO 120
  100 I=2
  110 IF(CA.LE.C(I)) GO TO 120
      I=I+1
      GO TO 110
  120 II = I- 1
      GO TO (200,300),K
  200 DO 220 J1=2,NT
      IF(TA.LE.T(J1)) GO TO 230
  220 CONTINUE
  230 DO 240 J2=2,NC
      IF(CA.LE.C(J2)) GO TO 250
  240 CONTINUE
  250 PC1=P(J1-1,J2)+(P(J1,J2)-P(J1-1,J2))*(TA-T(J1-1))/(T(J1)-T(J1-1))
      PC2=P(J1-1,J2-1)+(P(J1,J2-1)-P(J1-1,J2-1))*(TA-T(J1-1))/(T(J1)
     1-T(J1-1))
      PA=PC1+(PC2-PC1)*(CA-C(J2))/(C(J2-1)-C(J2))
      GO TO 1000
  300 DO 400 NN=2,NT
      IF(PA.LE.P(NN,I)) GO TO 450
  400 CONTINUE
  450 DO 500 MM = 2,NT
      IF(PA.LE.P(MM,II)) GO TO 600
  500 CONTINUE
  600 TCI=T(NN-1)+(T(NN)-T(NN-1))*(PA-P(NN-1,I))/(P(NN,I)-P(NN-1,I))
      TCII=T(MM-1)+(T(MM)-T(MM-1))*(PA-P(MM-1,II))/(P(MM,II)-P(MM-1,II))
  700 TA = TCII+(TCI-TCII)*(CA-C(II))/(C(I)-C(II))
 1000 RETURN
 1020 END
```

Figure B-30. MAPRDP Listing.

```
@ ELT LAGIN2,1,700417, 72189   , 1

      C      H0009
             SUBROUTINE LAGIN2 (IDMESS, X,     NP, ND, XA, YA, Y)
      C
      C      ROGER WRIGHT
      C      24 SEPTEMBER 1968
      C
      C      INTERPOLATION SUBROUTINE LAGIN2 --
      C      BCD --COMPATIBLE WITH IBM 360 FORTRAN IV AND UNIVAC 1108 FORTRAN V
      C
      C
      C      THIS PROGRAM PERFORMS A TABLE LOOKUP AND INTERPOLATION.  IT USES A
      C      BINARY SCHEME IN THE LOOKUP AND A LAGRANGIAN INTERPOLATION.  IF
      C      EXTRAPOLATION IS NECESSARY, 'LAGIN2' WILL ALWAYS DO SO LINEARLY.
      C      AN EXTRAPOLATION MESSAGE WILL BE PRINTED TO IDENTIFY THE
      C      INDEPENDENT ARRAY (FROM THE ARGUMENT 'IDMESS') AND THE ACTUAL
      C      VALUE OF THE INDEPENDENT VARIABLE SUBMITTED TO 'LAGIN2'.
      C                                ******
      C         THE SPECIAL FEATURE OF THIS VERSION OF LAGIN2 IS THAT THE VALUE
      C         OF 'MESAGE', CONTAINED IN THE FOLLOWING DATA STATEMENT, CAN BE
      C         COMPILED-IN TO PERMANENTLY ELIMINATE PRINTING (WHEN 'MESAGE'=1)
      C
             DATA MESAGE/1/
      C
      C         WITH 'MESAGE'=0, ALLOWING MESSAGES, THE SUBROUTINE IS H0008,
      C         WITH 'MESAGE'=1, DISALLOWING MESSAGES, THE SUBROUTINE IS H0009.
      C                                ******
      C
      C      INPUT ARGUMENTS....IDMESS=A NUMBER OF LESS THAN FOUR DIGITS WHICH
      C                                WILL BE PRINTED OUT IF EXTRAPOLATION WAS
      C                                NECESSARY.  IF 'IDMESS' IS LESS THAN OR
      C                                EQUAL TO ZERO, OR IF 'MESAGE' IS GREATER
      C                                THAN ZERO, NO MESSAGE WILL BE PRINTED.
      C                       .........X=AN ARRAY OF TABULATED VALUES OF THE
      C                                INDEPENDENT VARIABLE.  MUST BE
      C                                MONOTONICALLY INCREASING OR DECREASING.
      C                       ........NP=THE NUMBER OF ENTRIES IN THE 'X' ARRAY.
      C                       ........ND=THE NUMBER OF POINTS TO BE USED IN THE
      C                                LAGRANGIAN INTERPOLATION.
      C                       ........XA=THE VALUE OF THE INDEPENDENT VARIABLE
      C                                TO BE LOOKED UP.
      C                       .........Y=AN ARRAY OF TABULATED VALUES OF THE
      C                                DEPENDENT VARIABLE CORRESPONDING 1 FOR 1
      C                                TO ARRAY 'X'.
      C
      C      OUTPUT ARGUMENT........YA=THE VALUE OF THE DEPENDENT VARIABLE
      C                                CORRESPONDING TO 'XA'.
      C
             DIMENSION  X(2),  Y(2)
      C
      C      DETERMINE IF 'X' ARRAY IS INCREASING OR DECREASING.
         100 IF (X(1) - X(NP)) 110, 110, 120
      C
      C      'X' ARRAY INCREASING.
         110 ILO    = 1
             IHI    = NP
             INK=1
             GO TO 130
      C
      C      'X' ARRAY DECREASING.
         120 ILO    = NP
             IHI    = 1
             INK=-1
         130 IF(XA-X(ILO))150,420,140
         140 IF(XA-X(IHI))210,430,160
      C
      C      EXTRAPOLATION REQUIRED
         150 IHI=ILO+INK
             GO TO 170
         160 ILO=IHI-INK
         170 IF(IDMESS)200,200,180
```

Figure B-31. LAGIN 2 Listing (Sheet 1 of 2)

```
  180 IF (MESAGE.GT.0) GO TO 200
C
C     PRINT OUT EXTRAPOLATION MESSAGE.
  190 WRITE (6,1) IDMESS, XA
    1 FORMAT (1H 97X12H*LAGIN2, ID=I3,4H, X=E15.8)
C
  200 ID=2
      GO TO 260
C
C     SEARCH ARRAY 'X' FOR INDEXES OF VALUES SURROUNDING 'XA'.
  210 LOOK = (ILO+IHI+1)/2
      IF(XA-X(LOOK))220,440,230
  220 IHI=LOOK
      GO TO 240
  230 ILO=LOOK
  240 IF(IABS (IHI-ILO)-1)250,250,210
  250 ID=ND
C
C     FIND THE INDEXES OF VALUES IN 'X' WHICH ARE CLOSEST TO 'XA' FOR
C     LAGRANGIAN INTERPOLATION.
  260 IF(INK)270,270,280
  270 I1=IHI
      I2=ILO
      GO TO 290
  280 I1=ILO
      I2=IHI
  290 IF(ID-2)370,370,300
  300 DO 360 INT=3,ID
      I1P=I1-1
      I2P=I2+1
      IF(I1P)310,310,320
  310 IF (I2P - NP) 350, 350, 370
  320 IF (I2P - NP) 330, 330, 340
  330 IF(ABS (XA-X(I1P))-ABS (XA-X(I2P)))340,340,350
  340 I1=I1P
      GO TO 360
  350 I2=I2P
  360 CONTINUE
C
C
C     PERFORM LAGRANGIAN INTERPOLATION USING 'ID' POINTS STARTING WITH
C     'I1' THRU 'I2'.
  370 YA=0.0
      P=1.0
      DO 380 I=I1,I2
      P=P*(XA-X(I))
  380 CONTINUE
      DO 410 I=I1,I2
      F=P/(XA-X(I))
      DO 400 J=I1,I2
      IF(I-J)390,400,390
  390 F=F/(X(I)-X(J))
  400 CONTINUE
      YA=YA+F*Y(I)
  410 CONTINUE
      RETURN
C
C     ARGUMENT 'XA' IS EQUAL TO AN ELEMENT IN ARRAY 'X'.
  420 YA=Y(ILO)
      RETURN
  430 YA=Y(IHI)
      RETURN
  440 YA=Y(LOOK)
      RETURN
      END
```

Figure B-31. (Continued) (Sheet 2 of 2)

SYSTEM OPTIMIZATION NOMINAL SYSTEM RUN

CONFIGURATION DATA

SEPARATOR

ROTATING DRUM WITH PITOT TUBE LIQUID PICKUP

DRUM DIAMETER =	6.0000 INCHES	PITOT HEAD COEFFICIENT =	.1334
DRUM LENGTH =	4.0000 INCHES	PITOT DRAG COEFFICIENT =	.1238
PITOT TUBE RADIUS =	2.7000 INCHES	MINIMUM SEPARATOR VOLUME =	14.1372 CU.IN.
HEAT LEAK TO AMBIENT =	1.0000 BTU/HR/F		

COMPRESSOR

TWO STAGE VORTEX WITH SINGLE SIDED WHEELS

HEAT LEAK TO AMBIENT = 2.0000 BTU/HR/F

FLOW(CFM)	PRESS RATIO	POWER(WATTS)
2.0000	3.6000	108.0000
3.0000	3.3600	95.0000
4.0000	3.0600	82.0000
5.0000	2.7200	69.0000
6.0000	2.3600	56.0000
7.0000	2.0000	43.0000
8.0000	1.6000	30.0000
9.0000	1.2200	17.0000

RECUPERATOR

CROSS-COUNTER FLOW SHELL TUBE EXCHANGER WITH INLET ON SHELL SIDE

NUMBER OF TUBES =	124.0000	FLOW AREA ON SHELL SIDE =	.0065 FT-FT
NUMBER OF PASSES =	16.0000	FRONTAL AREA SHELL SIDE =	.0200 FT-FT
TUBE LENGTH =	20.0040 INCHES	BAFFLE FLOW AREA =	.0150 FT-FT
TUBE DIAMETER =	.1100 INCHES	AXIAL CONDUCTION AREA =	.0041 FT-FT
HEAT LEAK TO AMBIENT =	.1200 BTU/HR/F	AXIAL COND CONDUCTIVITY =	7.0000 BTU/HR/FT/F

CATALYST BED

WIRE MESH CATALYST BED WITH FLOW ALONG AXIS

BED LENGTH =	3.0000 INCHES	WIRE DIAMETER =	.0160 INCHES
BED DIAMETER =	2.2500 INCHES	MESH SIZE =	20.0000 WIRES/IN

CONDENSER

SPIRAL TUBE HX-BRINE ON INSIDE-STEAMON OUTSIDE -COUNTER FLOW

TUBE LENGTH =	144.1000 INCHES	FOULING FACTOR =	.0001
TUBE DIAMETER =	.1870 INCHES	HEAT LEAK TO AMBIENT =	1.3000 BTU/HR/F

FLUID LINES

	LENGTH(FT)	DIAMETER(IN)	UA(BTU/HR/F)
BRINE LINES			
CONDENSER TO FEED	2.0000	.2000	.2600
FEED TO SEPARATOR	2.0000	.2000	.2600
SEPARATOR TO DUMP	2.0000	.2000	.2600
DUMP TO CONDENSER	2.0000	.2000	.2600
VAPOR LINES			
SEPARATOR TO COMPRESSOR	14.0000	.4500	.0000
COMPRESSOR TO RECUPERATOR	6.0000	.4500	.4000
RECUPERATOR TO CONDENSER	6.0000	.4500	.3000

PERFORMANCE DATA

OPERATING CONDTIONS

SEPARATOR LEVEL =	50.0000 CU.IN	AMBIENT TEMPERATURE =	70.0000 DEG F
BRINE CONCENTRATION =	20.0000 PERCENT SOLIDS	FEED TEMPERATURE =	70.0000 DEG F
FEED CONCENTRATION =	4.0000 PERCENT SOLIDS	VENT PRESSURE =	2.0000 PSIA
CATALYST TEMPERATURE =	800.0000		

SYSTEM PERFORMANCE SUMMARY

WATER PROD. RATE =	1.7285 LB/HR	SEPARATOR POWER =	34.5244 WATTS
SEPARATOR PRESSURE =	1.4080 PSIA	COMPRESSOR POWER =	67.4700 WATTS
COMPRESSOR PRESS RATIO=	1.6135	CATALYST/RECUP. POWER =	22.4708 WATTS
BRINE FLOW RATE =	210.6250 LB/HR	VAPOR CARRYOVER =	.0000 LB/HR

SYSTEM STATE POINTS

		PRESSURE(PSIA)	TEMPERATURE(DEG F)
1	INLET TO FLASH VALUE	3.0016	125.0093
2	OUTLET OF PITOT TUBE	11.3204	115.6490
3	BRINE INLET TO CONDENSER	10.3595	115.5180
4	BRINE OUTLET FROM CONDENSER	5.8021	125.1676
5	SEPARATOR VAPOR OUTLET	1.4080	115.6490

Figure B-32. Output Sample (Sheet 1 of 2)

6	INLET TO COMPRESSOR	1.3480	115.6490
7	OUTLET OF COMPRESSOR	2.1751	165.6644
8	RECUPERATOR INLET	2.1578	129.1921
9	CATALYST BED INLET	2.1313	767.9847
10	CATALYST BED OUTLET	2.0367	800.0000
11	RECUPERATOR OUTLET	2.0339	161.2074
12	CONDENSER VAPOR INLET	2.0155	131.6848

COMPONENT PERFORMANCE DATA

SEPARATOR

SPEED	= 1800.0000 RPM	BRINE OUTLET PRES=	11.3204 PSIA
POWER	= 34.5244 WATTS	BRINE TEMPERATURE=	115.6490 DEG F
VAPOR PRESSURE	= 1.4080 PSIA	HEAT LEAK =	45.6490 BTU/HR

COMPONENT PERFORMANCE DATA

COMPRESSOR

INLET PRESS	= 1.3480 PSIA	POWER =	67.4700 WATTS
OUTLET PRESS	= 2.1751 PSIA	ADIABATIC EFF. =	26.3278 PERCENT
PRESS RATIO	= 1.6135	HOUSING TEMP. =	165.6644 DEG F
VOLUME FLOW	= 7.9662 CFM	HEAT LEAK =	191.2500 BTU/HR

COMPONENT PERFORMANCE DATA

RECUPERATOR

INLET TEMP.	= 129.1921 DEG F	INLET PRESS. =	2.1578 PSIA
OUTLET TEMP.	= 161.2074 DEG F	OUTLET PRESS. =	2.0339 PSIA
EFFECTIVENESS	= .9523	SHELL SIDE DEL P =	.0266 PSID
HEAT LEAK	= 49.2724 BTU/HR	TUBE SIDE DEL P =	.0028 PSID
POWER	= 22.4708 WATTS		

CATALYST BED

INLET TEMP.	= 767.9847 DEG F	BED DELTA P =	.0946 PSID
INLET PRESS.	= 2.1313		

COMPONENT PERFORMANCE DATA

CONDENSER

BRINE FLOW	= 210.6250 LB/HR	VAPOR FLOW =	1.7285 LB/HR
BRINE DELTA P	= 4.5575 PSID	VAPOR INLET P =	2.0155 PSIA
BRINE DELTA T	= 9.6496 DEG F	VAPOR DELTA P =	.0091 PSID
BRINE H	= 953.2998 BTU/HR/FT/FT/F	VAPOR SATUR T =	126.1811 DEG F
BRINE INLET T	= 115.5180 DEG F	VAPOR H =	2230.2158 BTU/HR/FT/FT/F
HEAT LEAK	= 73.0451 BTU/HR		

LINE DATA

	PRESSURE DROP(PSID)	HEAT LEAK(BTU/HR)
CONDENSER TO FEED	.4667	14.3436
FEED TO SEPARATOR	.4668	14.3230
SEPARATOR TO DUMP	.4804	11.8687
DUMP TO CONDENSER	.4805	11.8517
SEPARATOR TO COMPRESSOR	.0599	-.0000
COMPRESSOR TO RECUPERATOR	.0172	30.9713
RECUPERATOR TO CONDENSER	.0184	22.9338

Figure B-32. (Continued) (Sheet 2 of 2)

TABLE B-1

INPUT FORMAT FOR SYSTEM PERFORMANCE COMPUTER PROGRAM

10	11 20	21 30	31 40	41 50	51 60	61 70	71 80
NTH							
TH(1)	TH(2)			TH(NTH)			
HH(1)	HH(2)			HH(NTH)			
NTP	NCP						
TP(1)	TP(2)			TP(NTP)			
CP(1)	CP(2)			CP(NCP)			
PP(1,1)	PP(1,2)			PP(1,NCP)			
PP(2,1)	PP(2,2)			PP(2,NCP)			
PP(NTP,1)	PP(NTP,2)			PP(NTP,NCP)			
NTV	NCV						
TU(1)	TU(2)			TU(NTV)			
CU(1)	CU(2)			CU(NCV)			
VISB(1,1)	VISB(1,2)			VISB(1,NCV)			
VISB(2,1)	VISB(2,2)			VISB(2,NCV)			
VISB(NTV,1)	VISB(NTV,2)			VISB(NTV,NCV)			
NREN	NREL						
REN(1)	JREN(1)	REN(2)	JREN(2)			REN(NREN)	JREN(NREN)
RELL(1)	FANFR(1)	RELL(2)	FANFR(2)			RELL(NREL)	FANFR(NREL)
M							
DSEP(1)	ALHX(1)	DSEP(2)	ALHX(2)			DSEP(M)	ALHX(M)
TKSS	AFOUL						
NRET							
RET(1)	RET(2)			RET(NRET)			
RETF(1)	RETF(2)			RETF(NRET)			
RETJ(1)	RETJ(2)			RETJ(NRET)			
NRES							
RES(1)	RES(2)			RES(NRES)			
RESF(1)	RESF(2)			RESF(NRES)			
RESJ(1)	RESJ(2)			RESJ(NRES)			
NREB							
REB(1)	REB(2)			REB(NREB)			
REBEDF(1)	REBEDF(2)			REBEDF(NREB)			
AC	AF	TL	DT	ANT	ANP	AKC	ARXC
DBED	DW	ALBED	AMESH	EFFH	DPC	DPT	DPB
AB							
NPR	PB	TB	PE				
VFLO(1)	VFLO(2)			VFLO(NPR)			
PRC(1)	PRC(2)			PRC(NPR)			
POWC(1)	POWC(2)			POWC(NPR)			
UA(1)	UA(2)			UA(12)			
AL(1)	AL(2)			AL(12)			

TABLE B-1 (Continued)

D(1)	D(2)			D(12)			
HEAD							
DD	DL	OMEGA					
TAMB	TFEED	CONF	WDUMP	QHEAT	T(10)		
NCASE							
PCON(1)	XB(1)	ALEVEL(1)	JPRINT(1)	IFEED(1)			
↓	↓	↓	↓	↓			
PCON(NCASE)	XB(NCASE)	ALEVEL(NCASE)	JPRINT(NCASE)	IFEED(NCASE)			

TABLE B-2

DEFINITION OF INPUT VARIABLES FOR SYSTEM PERFORMANCE COMPUTER PROGRAM

Variable	Definition	Units
NTH	Number of points in TH and HH arrays	-
TH	Temperatures of heat of vaporization array	^{0}F
HH	Heat of vaporization of water	Btu/lb
NTP	Number of temperatures in PP array	-
NCP	Number of concentrations in PP array	-
TP	Temperatures in PP array	^{0}F
CP	Concentration in PP array	-
PP	Vapor pressure of urine concentrates	psia
NTU	Number of temperatures in VISB array	-
NCU	Number of concentrations in VISB array	-
TV	Temperatures in VISB array	^{0}F
CU	Concentrations in VISB array	-
VISB	Viscosity of urine concentrates	cp
NREN	Number of data points in REN and JREN arrays	-
NREL	Number of data points in RELL and FANFR arrays	-
REN	Reynolds number of flow in circular tubes	-
JREN	J factor for flow in circular tubes	-
RELL	Reynolds number for flow in circular tubes	-
FANFR	Fanning friction factor for flow in circular tubes	-
M	Number of increments in condenser tube	-
DSEP	Separation of adjacent wraps of condenser tube	in.
ALHX	Length of increment of condenser tube	in.
TKSS	Thermal conductivity of condenser tube	Btu/hr/ft/^{0}F
AFOUL	Fouling factor for condenser tube	hr-ft^{2}-^{0}F/Btu
NRET	Number of data points in RET, RETF and RETJ arrays	-
RET	Reynolds number for flow inside recuperator tubes	-
RETF	Friction factor for flow inside recuperator tubes	-
RETJ	J factor for flow inside recuperator tubes	-

TABLE B-2 (Continued)

Variable	Definition	Units
NRES	Number of data points in RES, RESF, RESJ arrays	-
RES	Reynolds number for flow over recuperator tubes	-
RESF	Friction factor for flow over recuperator tubes	-
RESJ	J factor for flow over recuperator tubes	-
NREB	Number of data points in REB and REBEDF arrays	-
REB	Reynolds number for flow through catalyst bed	-
REBEDF	Friction factor for flow through catalyst bed	-
AC	Minimum flow area/pass in recuperator	ft^2
AF	Frontal flow area/pass in recuperator	ft^2
TL	Tube length in recuperator	ft
DT	Recuperator tube diameter	ft
ANT	Number of tubes in recuperator	-
ANP	Number of passes over tubes in recuperator	-
AKC	Thermal conductivity of recuperator tubes	Btu/hr/ft/^{0}F
ARXC	Recuperator area for axial conduction	ft^2
DBED	Diameter of catalyst bed	in.
DW	Diameter of screen wire for catalyst bed	in.
ALBED	Length of catalyst bed	in.
AMESH	Mesh size of catalyst bed screen	1/in.
EFFH	Initial guess on recuperator effectiveness	-
DPC	Initial guess on catalyst bed pressure drop	psia
DPT	Initial guess on recuperator tube side pressure drop	psia
DPB	Initial guess on recuperator shell side pressure drop	psia
AB	Flow area through recuperator baffles	ft^2
NPR	Number of points in VFLO, PRC, POWC arrays	-
PB	Inlet pressure for PRC and POWC arrays	psia
TB	Housing temperature for PRC and POWC arrays	^{0}F
PE	Bearing and windage losses of compressor	watts
VFLO	Volumetric inlet flow of compressor	cfm
PRC	Inlet to outlet pressure ratio of compressor	-

TABLE B-2 (Continued)

Variable	Definition	Units
POWC	Compressor power at TB, PB	watts
UA	Heat transfer coefficient X area of system elements	Btu/hr/ ^oF
AL	Line length of system line elements	ft
D	Line diameter of system line elements	in.
HEAD	Descriptive title of case to be run	-
DD	Separator bowl diameter	in.
DL	Separator bowl length	in.
OMEGA	Separator rotational speed	rpm
TAMB	Ambient temperature	^oF
TFEED	Temperature of feed	^oF
CONF	Concentration of feed	-
WDUMP	Flow rate of dump	-
QHEAT	Power in trim heater	watts
T(10)	Temperature of catalyst bed	^oF
NCASE	Number of operational cases to be run for this system configuration	-
PCON	Condenser vent pressure	psia
XB	Brine concentration	-
ALEVEL	Brine volume in brine loop	$in.^3$
JPRINT	Control on print (1)-will print only performance summary (2)-will print component detailed performance	-
IFEED	Control on urine feed (1)-feed at rate equal to production rate (0)-no feed	-